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An interactive Matrix Interpretive System for the IBM 360/67.

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THESIS

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FOR THE IBM 360/67

by

Robert Douglas Little

June 1970

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For the IBM 360/67

by

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ABSTRACT

The Matrix Interpretive System devised by Wilson and modified by Cantin has been transformed into an interactive program operable under a time sharing system. Several new commands have been added to extend the usefulness of the code and give it the capability to offline read, write and punch data, to plot graphs and contour maps and to integrate simple polynomial expressions.

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ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Professor E. L. Wilson of the University of California, the originator of the program. He is also grateful to Professor Gilles Cantin of the Naval Postgraduate School, his advisor, for his constructive supervision and encouragement throughout this work.

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I. INTRODUCTION

A. GENERAL DESCRIPTION

Many engineering problems in such fields as steady-state temperature distribution [Ref. 1], stress in elastic structures [Ref. 2], and fluid flows [Ref. 3] can be formulated as problems of numerical linear algebra. Until the advent of modern digital computers, all but the simplest of these problems had to be reserved to specialists for solutions. Even problems of moderate size required a considerable computational effort. The computer changed all of this. All of the simple matrix operations like multiplication, transposition, solution of eigen systems can be coded to solve individual problems. The computer program described in this report integrates a number of standard subprograms of linear algebra [Refs. 4,5,6,7] into a problem oriented computer language. This program, heretofore called: Matrix Interpretive System was coded in FORTRAN IV. The resulting matrix operations sub-language has a syntax and rules of its own as well as a certain number of diagnostic messages that can be automatically returned to the user of the language. The basic specification for the design of the language structure was that it had to be simple enough to be used by persons unfamiliar with computer programming. As written, the language could be used to solve stacks of problems sequentially; if an error is found in one of the problems a message is printed and a solution for the next problem is attempted. To be effective in a conversational mode at a remote station, the program had to be heavily modified so as

to leave effective control of the flow of operations to the user. This version of the code is called: Interactive Matrix Interpretive System.

The Interactive Matrix Interpetive System is a general program written in FORTRAN IV [Ref. 8], it is a problem oriented sub-language. The entire program is coded in double precision arithmetic. The only subroutines which are used but are not contained in the program are a square root and a natural log subroutine. The program uses 160,000 bytes of core storage.

B. HISTORICAL BACKGROUND

The original program was developed by Professor E. L. Wilson of the University of California in April 1963 for an IBM 7094. It was later adapted by Professor G. Cantin of the Naval Postgraduate School for a CDC 1604 in February 1966 and for the IBM 360/67 in August 1968.

C. OBJECTIVES

The objectives of the author's work have been to:

1. transform the program into an interactive system operable under time sharing from a remote typewriter station;

2. add operations to extend the capabilities of the program;

3. create a "USER'S MANUAL" to facilitate the use of the program.

II. <u>GENERAL PROGRAM OPERATION</u>

The Interactive Matrix Interpretive System will be referred to as IMIS in this and following sections of this report. IMIS is written in FORTRAN IV language for the IBM 360/67 time sharing system available at the Naval Postgraduate School (CP/CMS). A different version called DSMIS is used for batch processing. All operations are performed in double precision arithmetic. Matrices are stored internally in a single dimensional array, A, that is 10,000 double words in size. Matrix names are stored in an array called NAME. Arrays, NROW and NCOL, are used to store the number of rows and columns of each matrix.

The following is a brief description of the function and operation of most of the subroutines of IMIS. Some of the subroutines are straightforward and will not be discussed. A flow diagram of the program is presented in Figure 1.

A. MAIN PROGRAM AND SERVICE SUBROUTINES

1. <u>Main Program</u>

The Main program is used only to initialize internal variables and to call the main service subroutine, SMIS1.

2. <u>Main Working Subroutine (SMIS1)</u>

SMIS1 is the general working subroutine. Some of the operations such as duplication of a matrix and envelope of a matrix are carried out in SMIS1. The other operations are carried out in subroutines which are called from SMIS1. Most of the error messages are called from SMIS1.

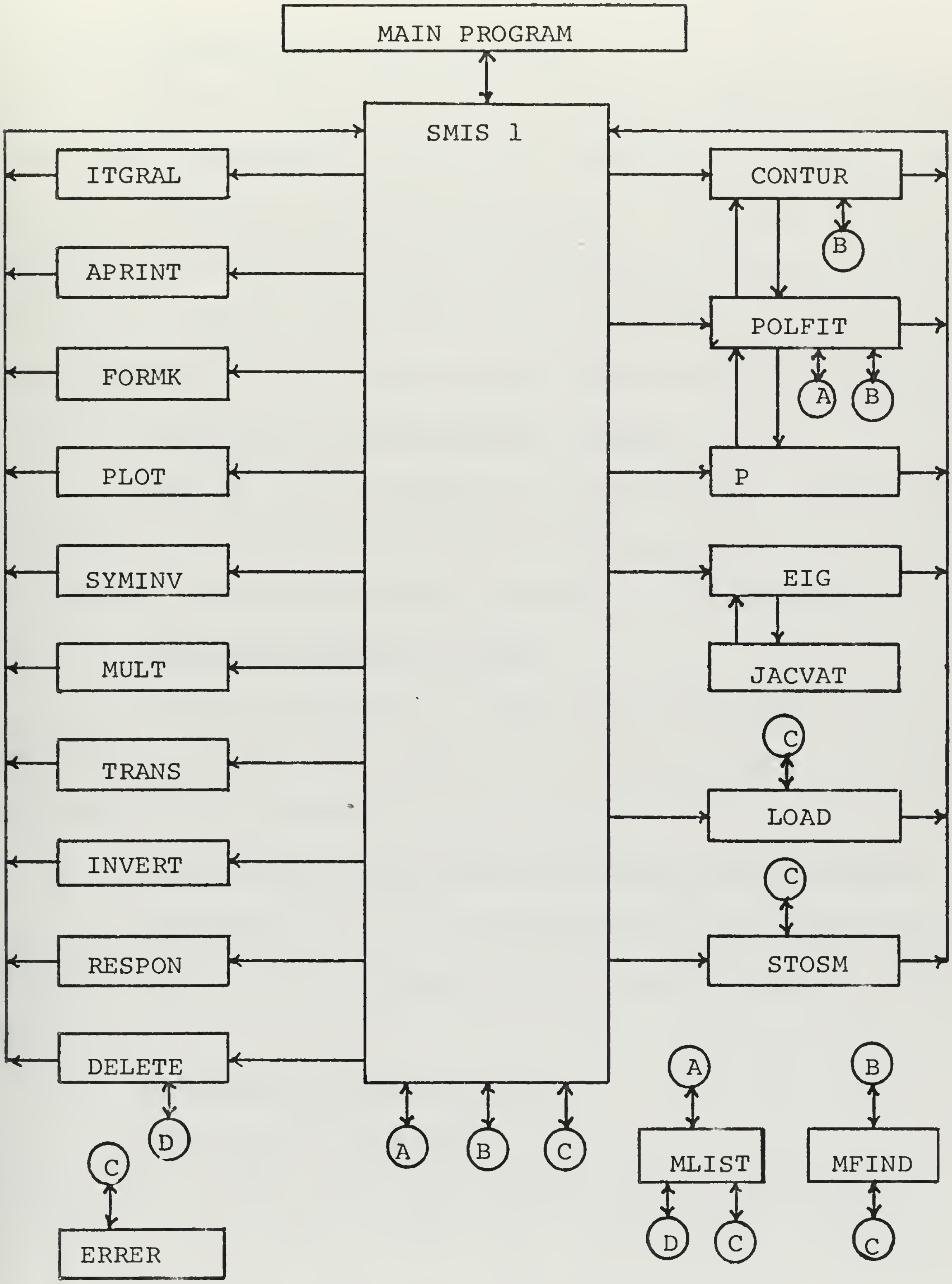

Figure 1. Functional Flow Diagram

3. Listing of a Matrix (MLIST)

MLIST stores each matrix by name, number of rows and columns and starting position in the array, A. It checks the name of a new matrix to be stored against the names of previously stored matrices to see if the name has been used before. If there is another matrix with the same name, the previously stored matrix will be deleted before the new matrix is stored.

4. Printing of Error Messages (ERRER)

When an error is made in an operational command, ERRER is called. It prints out an error message, deletes the current operational command and returns control to the typewriter.

5. Locating a Matrix (MFIND)

Locates the matrix or matrices to be used in an operation. It finds the number of rows and columns of a matrix and the starting position in the array A.

6. Calculating Eigenvalues and Eigenvectors (JACVAT)

Determines all of the eigenvalues and eigenvectors of a matrix. It uses the threshold cyclic Jacobi rotation method [Ref. 4].

7. Formation of Matrix N (P)

The bicubic polynomial,

$$P=C_1X^3Y^3+C_2X^3Y^2+C_3X^3Y+C_4X^3+C_5X^2Y^3+C_6X^2Y^2+C_7X^2Y+C_8X^2+$$

$$C_9XY^3+C_{10}XY^2+C_{11}XY+C_{12}X+C_{13}Y^3+C_{14}Y^2+C_{15}Y+C_{16}$$

is used in the polynomial fit operation. This polynomial can be written as

$$P = \langle F_i \rangle \{C_i\}_{i=1,2,\ldots,16}$$

where $\langle F_i \rangle = \langle X^3Y^3, X^3Y^2, X^3Y, X^3, X^2Y^3, X^2Y^2, X^2Y, X^2,$

$XY^3, XY^2, XY, X, Y^3, Y^2, Y, 1 \rangle$

and $\{C_i\} = \langle C_1, C_2, \ldots, C_{16} \rangle^T$. In the POLFIT operation, values of P at all of the sixteen nodal points of the grid shown in Figure 2 must be used to solve for all of the unknown coefficients of the polynomial using the following matrix equation:

$$\{P_i\} = [N] \{C_i\}_{i=1,2,\ldots,16}$$

where

$$[N] = \begin{bmatrix} \langle F_i^{(1)} \rangle \\ \langle F_i^{(2)} \rangle \\ \cdot \\ \cdot \\ \cdot \\ \langle F_i^{(16)} \rangle \end{bmatrix}$$

Subroutine P forms matrix N for use in the POLFIT operation. The bicubic polynomial, P, will be referred to as CUPOL in the following sections.

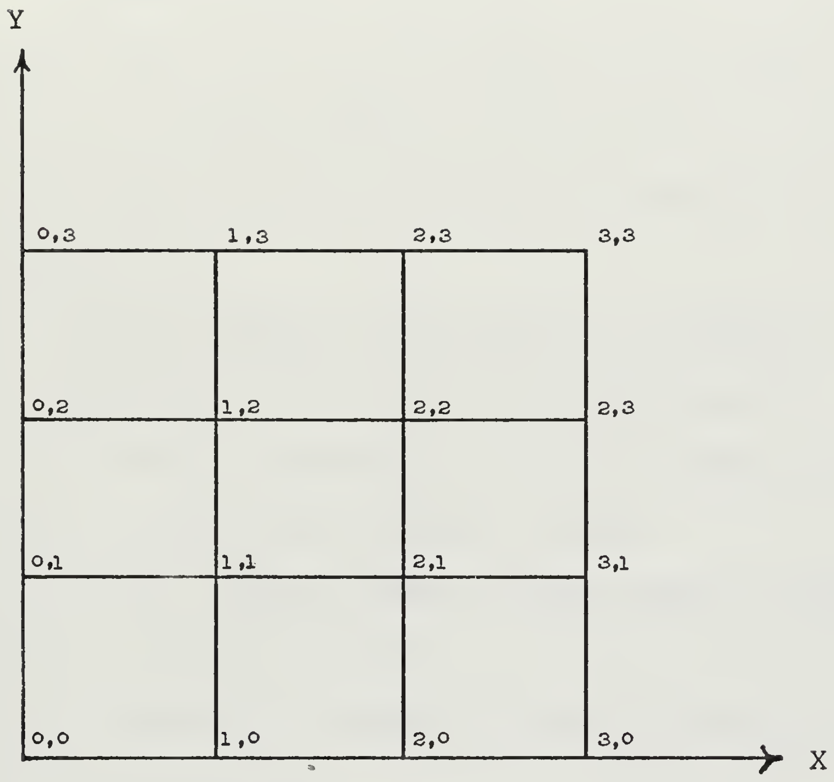

Figure 2. Grid For Subroutine P

B. OPERATION SUBROUTINES

1. Inverting a Symmetric Matrix (SYMINV)

SYMINV inverts a symmetric matrix, A, by Gauss elimination [Ref. 4]. If the matrix is not symmetric, it takes the average of the two numbers, A(i,j),A(j,i), and replaces both by the average value and prints a warning that the matrix was not symmetric.

2. Adding, Removing and Storing a Submatrix (STOSM)

STOSM is called to do three operations.

a) Store a submatrix at an indicated position in a matrix when called by the command, STOSM.

b) The command, RMVSM, calls STOSM to remove a submatrix from the original matrix.

c) ADDSM calls STOSM to add a submatrix to a matrix at an indicated position.

3. Function Generation (FUNGN)

This subroutine takes a function described by a set of points $(X_i,Y_i)_{i=1,2,...,n}$, not necessarily equally spaced, and calculates, by straight line interpolation, ordinates at equally spaced values of X.

4. Printing of Graphs (PLOT)

PLOT prints a 10 inch by 10 inch graph of 1 to 4 curves. It automatically scales the graph to the maximum and minimum values of X and Y. The axes are plotted as

a) X------X

b) Y------Y

with the characters, X and Y, appearing at every inch on their respective axes. When all of the points are plotted on one side of either axis, an offset axis replaces the real axis and is indicated by

a) A------A offset X axis

b) B------B offset Y axis

The origin of the axes and the X and Y scale factors are calculated and printed below the graph.

5. Determining the Coefficients of a Bicubic Polynomial (POLFIT)

The 16 unknown coefficients of a bicubic polynomial surface can be determined in terms of 16 known values of the polynomial at 16 known values of the independent variables.

POLFIT solves the matrix equation,

$$[N] \{C\} = [P]$$

for the matrix of unknown coefficients, C, where matrix N is formed by the subroutine P. Matrix P is a matrix of the values of CUPOL at each nodal point and is the input to POLFIT.

6. Printing Contour Maps (CONTUR)

CONTUR prints a contour map of CUPOL. There are 21 possible contour lines which are represented by the alphabetic letters, A through J, O, Q through Z. The input is either the coefficients of CUPOL with the upper and lower limits of X and Y or the values of the function at the grid points used for POLFIT. In the latter case, POLFIT is called and the coefficients of CUPOL are calculated.

CUPOL is then scanned over the ranges of X and Y to determine the maximum and minimum Z ordinate. The range of Z is divided into 42 equal parts represented by alphabetic characters and blanks assigned to alternating contour values. CUPOL is then evaluated at each point on a line, the correct character inserted and the line printed.

7. Formation of a 2 by 2 Stiffness Matrix (FORMK)

FORMK forms the stiffness matrix [Ref. 9],

$$[K] = \begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix}$$

for a simply supported beam having length, L, Young's Modulus, E, moment of inertia, I, shear modulus, G, and effective shear area, $\bar{A}$.

The stiffness coefficients are:

$$k_{11} = \frac{2EI}{L}\left(\frac{2+\beta}{1+2\beta}\right) = k_{22}$$

$$k_{12} = \frac{2EI}{L}\left(\frac{1-\beta}{1+\beta}\right) = k_{21}$$

where

$$\beta = \frac{6EI}{L^2\bar{A}G}$$

The matrix equation,

$$\begin{Bmatrix} M_1 \\ \\ M_2 \end{Bmatrix} = [K] \begin{Bmatrix} \theta_1 \\ \\ \theta_2 \end{Bmatrix}$$

relates end moments, M_1, M_2, to their corresponding rotations, θ_1, θ_2 as shown in Figure 3.

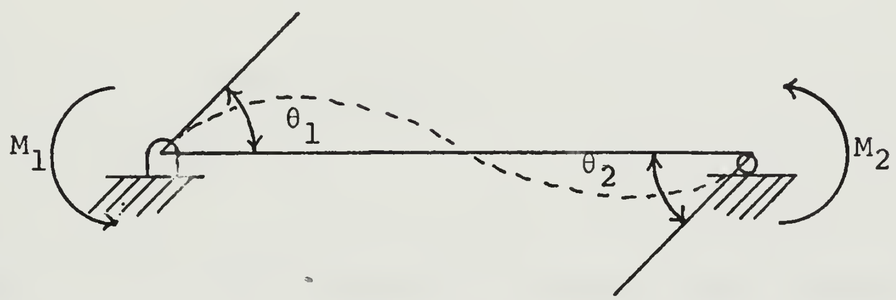

Figure 3. Simple Beam

8. Numerical Integration (ITGRAL)

The subroutine, ITGRAL, is capable of performing numerical integration of one and two dimensional functions described by discrete sets of points, either by Simpson's rule, or, if the function to be integrated is known, by Gaussian quadrature.

9. Numerical Integration of a Set of Differential Equations (RESPON)

In the study of vibrations of systems with many degrees of freedom, the following system of ordinary differential equations governs the problem:

$$[M]\ \{\ddot{X}\} + [C]\ \{\dot{X}\} + [K]\ \{X\} = \{P\} \qquad (1)$$

where

[M] is the mass matrix,

[C] is the damping matrix

and

[K] is the stiffness matrix.

In general, if

$$\{X\} = [V]\ \{x\} \qquad (2)$$

where matrix [V] is the matrix of undamped mode shapes and {x} is the vector of the time dependent amplitude function for each mode, we get after substitution of (2) into (1):

$$[M]\ [V]\ \{\ddot{x}\} + [C]\ [V]\ \{\dot{x}\} + [K]\ [V]\ \{x\} = \{P\} \qquad (3)$$

After premultiplication by $[V]^T$ and the use of the orthogonality properties of normal modes:

$$[V]^T\ [M]\ [V] = [\ulcorner m \lrcorner]$$

$$[V]^T\ [K]\ [V] = [\ulcorner k \lrcorner] = [\ulcorner \omega^2 m \lrcorner]$$

$$[V]^T\ [C]\ [V] = [\ulcorner c \lrcorner] = [\ulcorner 2\lambda\omega m \lrcorner]^{(a)}$$

(a) Such an orthogonality condition imposes some restrictions on the form of the damping matrix [C].

where

$$\lambda = \frac{c_i}{2m_i\omega_i}$$

and using the notation

$$[V]^T \{P\} = \{p\}$$

we get

$$[\ulcorner m \lrcorner] \{\ddot{x}\} + [\ulcorner 2\lambda\omega m \lrcorner] \{\dot{x}\} + [\ulcorner \omega^2 m \lrcorner] \{x\} = \{p\} \tag{4}$$

or

$$\{\ddot{x}\} + [\ulcorner 2\lambda\omega \lrcorner] \{\dot{x}\} + [\ulcorner \omega^2 \lrcorner] \{x\} = \{p^*\} \tag{5}$$

where $p_i^* = p_i/m_i$.

This last set of equations is completely decoupled and can easily be numerically integrated. The subroutine RESPON performs this task.

III. OPERATIONAL COMMANDS

The following is a list of the operations that IMIS contains. The operations must conform to the standard format shown in Figure 4. OPERATION stands for any of the symbolic command names mentioned below. A, B, C and D are matrices used as arguments of the operation. N1, N2, N3 and N4 are four integer arguments that must always be right justified. S1 and S2 are two floating point arguments. The arguments can be input or output values and are not all necessary for each command.

There are two versions of the matrix interpretive system in use at the Naval Postgraduate School. One is for time sharing and one for batch processing. The commands denoted by a "*" can only be used in conjunction with the time sharing option. The READ, WRITE and PUNCH commands make use of sequential input/output files which are available with the FORTRAN IV language [Ref. 8].[b]

The READ command uses the file FT04F001. This file is used to load matrices into IMIS from punched cards and is read into the computer prior to executing IMIS. Any data stored in the file is automatically erased when new data is read into the file.

File FT08F001 is used to store any output which the user wants to print offline. This file is not automatically erased

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[b] A certain knowledge of the CP/CMS time sharing system is needed when using a remote terminal of the computer. It is presumed that the reader is already familiar with this system [Ref. 10].

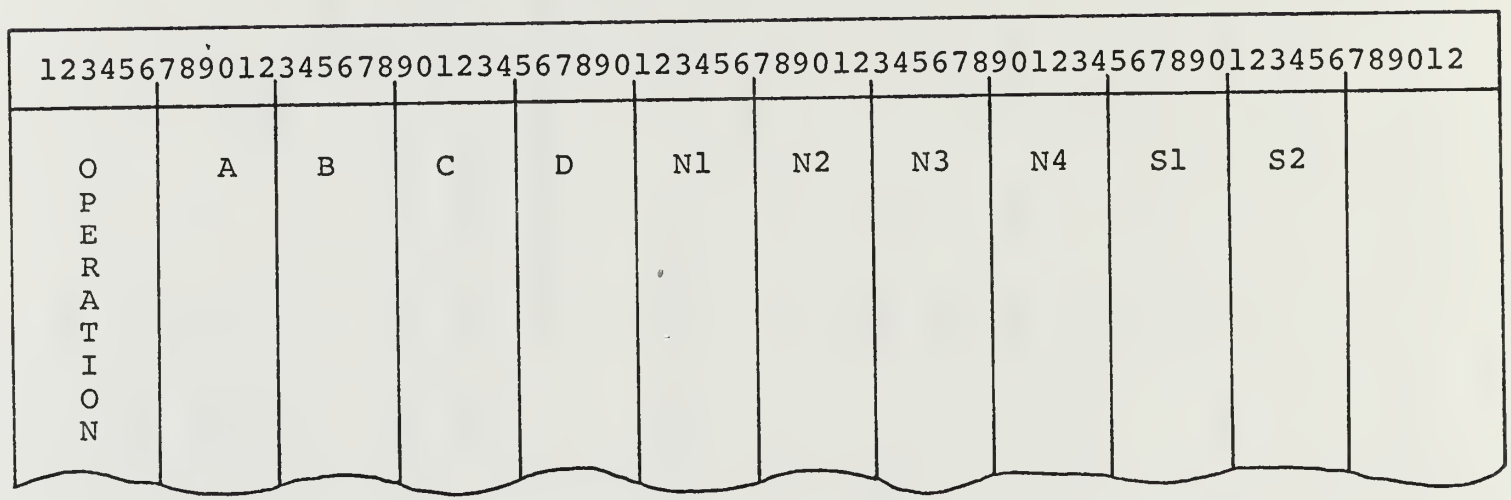


Figure 4. Standard Format

when new data is read into the file. New data is appended to the data that is already stored in the file. Therefore, the file must be erased before executing IMIS. To erase the file, the command,

ERASE$_b$FILE$_b$FT08F001

is used. After exiting from IMIS, the command,

OFFLINE$_b$PRINTCC$_b$FILE$_b$FT08F001

will cause the file to be printed on the offline printer.

The command, PUNCH, uses file FT07F001 to store data to be punched onto cards. This file appends new data at the end of old data so the file must be erased before using IMIS. The command,

ERASE$_b$FILE$_b$FT07F001

erases the file. To offline punch the data stored in the file, the command,

OFFLINE$_b$PUNCH$_b$FILE$_b$FT07F001

is issued after exiting from IMIS. Examples of the use of these files are given in the sample problems. The operational commands are:

START — This command causes the elimination of all matrices which are in core storage and must be the first command used in the solution of a problem. If an error is found during execution of a command, an error message is printed on the

typewriter, the current command eliminated and control returned to the typewriter. If an error is found during the execution of a problem with DSMIS, the current problem is automatically deleted and the remaining cards scanned until a new START or STOP command is found.

LOAD   Matrix Load:

A = Name of matrix to be loaded.

N1 = Number of rows of matrix A.

N2 = Number of columns of matrix A.

N3 = Format control indicator for the data.

The elements of the matrix are typed or punched on cards row-wise after the LOAD command according to one of the options determined by the value of N3:

a. if N3= 1 or blank, the format is (12F6.0). A maximum of twelve numbers per line, using as many lines as required to write the entire matrix must be used. If the decimal point is omitted, it is assumed to be at the extreme right of the field.

b. if N3= 2, (6F12.0), 6 numbers per line in fields of 12 columns.

c. if N3= 3, (4F18.0), 4 numbers per line in fields of 24 columns.

d. if N3= 4, (3F24.0), 3 numbers per line in fields of 24 columns.

PRINT Matrix Print:

A = Name of matrix to be printed.

N1= Number of lines, which follow the PRINT command, to be printed as a label for the matrix. Column 13 of the command card is used for carriage control in DSMIS only. A one in column 13 will cause the matrix to be printed on a separate output page.

REMARK This operation causes the number of lines designated by N1, which follow the operation, to be printed as remarks.

STOP This operation ends a run of problems and is the last command to be issued in a stack of problems. It can be used only once per run.

ZERO Formation of a Null Matrix:

A = Name of null matrix.

	N1= Number of rows of matrix A.
	N2= Number of columns of matrix A.
ADD	Matrix Addition - [A] + [B] = [A]
	Matrix A is replaced by the sum of matrices A and B.
SUB	Matrix Subtraction - [A] - [B] = [A]
	Matrix A is replaced matrix A minus matrix B.
MULT	Matrix Multiplication - [A] $\cdot$ [B] = [C]
	The product of matrix A times matrix B is generated and defined by matrix C.
TRANS	Matrix Transpose - [B] = $[A]^T$
	The transpose of matrix A is generated and defined by matrix B.
INVERT	Matrix Inversion - [A] = $[A]^{-1}$
	Matrix A is replaced by the inverse of itself.
SYMINV	Symmetric Matrix Inversion - [A] = $[A]^{-1}$
	Symmetric matrix A is replaced by the inverse of itself.
STOSM	Store Submatrix in a Matrix:
	A = Name of large matrix.
	B = Name of submatrix to be stored.
	N1= Row number in large matrix of first element of submatrix.
	N2= Column number in large matrix of first element of submatrix.

Elements of A are replaced by elements of B in designated area.

STODG — Store Row Matrix on Diagonal of Matrix:

A = Name of square matrix.

B = Name of row matrix to be stored on diagonal of matrix A.

Diagonal elements of A are replaced by elements of B.

SCALE — Scalar Multiplication - $[A] = S1 \cdot [A]$

ADDSM — Add Submatrix to a Large Matrix:

A = Name of large matrix.

B = Name of submatrix to be added into large matrix.

N1= Row number in large matrix of first element of submatrix.

N2= Column number in large matrix of first element of submatrix.

RMVSM — Extracts Submatrix [B] from [A]:

A = Name of large matrix.

B = Name of submatrix defined as matrix.

N1= Row number in large matrix of first element of submatrix.

N2= Column number in large matrix of first element of submatrix.

N3= Number of rows in submatrix.

N4= Number of columns in submatrix.

Matrix A is not modified.

LOG	The Log of each Element Each element in the matrix A is replaced by the natural log of the element.
MSCALE	Scalar Multiplication Each element in the matrix A is replaced by B times the element where B has previously been defined as a 1 by 1 matrix.
RMVDG	Extracts Row Matrix B from Diagonal of Square matrix A. A = Name of square matrix. B = Name of row matrix composed of the diagonal elements of matrix A. Matrix A is not modified.
EIGEN	Eigenvalues and Eigenvectors: The eigenvalues and eigenvectors of the system, $[A][X]=\lambda[B][X]$, are determined where [A] is a symmetrical matrix and [B] is a diagonal matrix of positive elements stored as a row matrix. A = Name of matrix A. B = Name of matrix B. C = Name of matrix of eigenvectors stored row-wise.

D = Name of row matrix of eigenvalues, λ.

N1= The number of eigenvectors to be calculated. The ordering of eigenvectors and eigenvalues is determined by the sign of N1 as follows:

a. If N1 is positive, eigenvalues are arranged in descending order.

b. If N1 is negative, eigenvalues are arranged in ascending order.

N2= Eigenvector normalizing.

a. If N2 is blank:

Eigenvectors are normalized so that $[C][B][C]^T = [I]$

b. If N2 is 1:

Eigenvalues are normalized so that $[A] = [C]^T [\ulcorner\lambda\lrcorner][C]$

SQREL Square Root of Each Element

Each element in the matrix A is replaced by the square root of itself.

INVEL Inversion of Each Element

Each element in the matrix A is replaced by the reciprocal of itself.

DELETE Matrix Deletion

The matrix A is eliminated from core storage.

DUPL Matrix Duplication:

A = Name of matrix to be duplicated.

B = Name of matrix defined to be identical with matrix A.

ENVEL Envelope Value of Matrix

The maximum absolute value in each row of matrix A is printed along with its column number times an interval.

A = Name of matrix A.

S1= Interval between columns.

RESPON Numerical Integration of a Set of Differential Equations:

$$\{\ddot{x}\}+2\lambda[\ulcorner\omega\lrcorner]\{\dot{x}\}+[\ulcorner\omega^2\lrcorner]\{x\}=\{S\}P(t)$$

with initial conditions, $x(0)=\dot{x}(0)=0$.

A = Name of a row matrix containing the diagonal elements of matrix $[\ulcorner\omega\lrcorner]$. The dimension of A must be (lxn) where n is the number of equations in the set.

B = Name of a column matrix containing the elements of {S}. The dimension of B must be (nxl).

C = Name of a row matrix containing the values of the function P(t) evaluated at equal intervals, Δt:

$P(0), P(\Delta t), P(2\Delta t), \ldots, P(m\Delta t)$

The dimension of C depends on the choice of Δt which must be small for accurate results. The size of Δt should be determined by actual numerical experimentation with the command.

D = Name of the output matrix containing the calculated values of the variables as shown in Figure 5.

N1= Output interval i. The values of the n unknowns, {x}, are printed at $i\Delta t, 2i\Delta t, 3i\Delta t, \ldots$; if i=1, all of the values are printed.

S1= Value of the damping ratio, λ.

S2= Time increment, Δt, used in the numerical integration.

$$\begin{bmatrix} x_1(i\Delta t), x_1(2i\Delta t), x_1(3i\Delta t), \ . \ . \ . \\ x_2(i\Delta t), x_2(2i\Delta t), x_2(3i\Delta t), \ . \ . \ . \\ \cdot \\ \cdot \\ \cdot \\ x_n(i\Delta t), x_n(2i\Delta t), x_n(3i\Delta t), \ . \ . \ . \end{bmatrix}$$

Fig. 5. OUTPUT MATRIX, D, FOR RESPON

FUNGN Function Generation:

A = Name of matrix which defines a function in terms of line segments $X_1,Y_1;X_2,Y_2;\cdots;X_n,Y_n$. (Nx2)

B = Name of matrix to be formed which is composed of the y ordinates at equal x ordinate intervals of the function defined by matrix A.

N1= Number of y ordinates to be generated. The first ordinate will be equal to Y_1.

S1= X ordinate interval.

FORMK Forms a 2x2 Element Stiffness Matrix:

A = Name of matrix to be formed.

The line following the command is as follows:

a. Columns 1-12 Moment of inertia of member, I.

b. Columns 13-24 Effective shear area of member, $\bar{A}$.

c. Columns 25-36 Length of member, L.

d. Columns 37-48 Modulus of elasticity of member, E.

The shear modulus, G, is assumed to be equal to E/2.4.

PUNCH Punches Matrix onto Cards:

A = Name of matrix to be punched.

N1= Number of comment cards to be punched as a heading for matrix A.

After the PUNCH command is issued, the next line contains the format elected by the user as follows:

(NNTRR.SS)

where

NN= Number of elements per card.

RR= Field width per element.

SS= Number of significant digits.

T = Type of data field. T must be a standard F or D Fortran format.

* READ Loads Matrices from file FT04F001

The load operation card must have a 1. in S1. The last card must be a Continue Operation card.

* CONT Continue Operation

S1= 1.

Indicates that all matrices in file FT04F001 have been loaded into IMIS.

* WRITE Writes Matrix into File FT08F001:

A = Name of matrix to be written.

N1= Number of lines of remarks to be

written as a label for the matrix A.

N2 must be equal to 1.

PLOT

Plots One to Four Curves Described by Sets of Points Contained in Matrices A, B, C, D:

A = First matrix to be plotted on one graph. Plotted as a "+".

B = Second matrix to be plotted on one graph. Plotted as a "*".

C = Third matrix to be plotted on one graph. Plotted as a "O".

D = Fourth matrix to be plotted on one graph. Plotted as a ".".

* N3= 1. Offline print indicator. Graph will be stored in file FT08F001

N4= Number of lines of remarks to be printed at bottom of graph.

Matrices to be plotted do not have to have the same number of points. They have to be entered as N by 2 matrices with the first column the X co-ordinates and the second column the Y co-ordinates. When plotting more than one curve on the same graph, a conflict may arise if more than one curve passes

through the same point. The symbol printed at that point is determined by the following order: D, C, B and A.

POLFIT Determines the Coefficients of CUPOL:

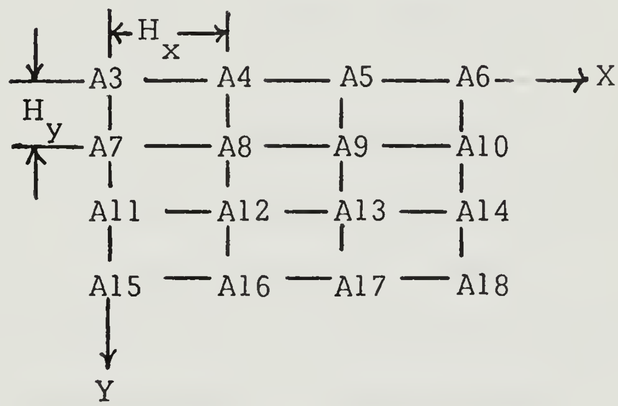
A = Input matrix. (18x1)

B = Output matrix of coefficients of CUPOL, $(C_1, C_2, \ldots, C_{16})$

where

$A(1) = H_x$

$A(2) = H_y$



and

$$CUPOL = C_1X^3Y^3 + C_2X^3Y^2 + C_3X^3Y + C_4X^3 +$$
$$C_5X^2Y^3 + C_6X^2Y^2 + C_7X^2Y + C_8X^2 +$$
$$C_9XY^3 + C_{10}XY^2 + C_{11}XY + C_{12}X +$$
$$C_{13}Y^3 + C_{14}Y^2 + C_{15}Y + C_{16}$$

CONTUR Contour Maps CUPOL:

N2= Number of lines of comments.

N3= Input type indicator.

a. N3= Blank or 1.

A = Input matrix. Same as for POLFIT command. (18x1)

B = Output matrix of coefficients of CUPOL. (16x1)

b. N3= 2

A = Input matrix. (20x1)

A(1) = Lower bound of X.

A(2) = Upper bound of X.

A(3) = Lower bound of Y.

A(4) = Upper bound of Y.

A(5) through A(20) are the coefficients of CUPOL.

* N4= Offline print indicator. Stores contour map in file FT09F001.

ITGRAL Integration of Functions Represented by Discrete Values or Polynomials:

A = Input matrix. (Rx1)

N3= Integration type indicator:

a. If N3= 1, Simpson's Rule for one dimension. R must be even.

$A(1) = H_X$

A(2) through A(R) are evenly spaced values of function.

b. If N3 = 2, Simpson's Rule for two dimensions.

A(1) = H_x

A(2) = H_y

A(3) through A(R) are values of function entered row-wise as for POLFIT.

R = N^2+2, N must be odd.

There must be the same number of values in both directions. H_x and H_y can be unequal.

c. If N3= 3, Gauss Quadrature for one dimension.

A(1) = Lower bound of X.

A(2) = Upper bound of X.

A(3) through A(14) are the coefficients of an 11th degree polynomial:

$$A_3X^{11}+A_4X^{10}+A_5X^9+A_6X^8+A_7X^7+A_8X^6+$$

$$A_9X^5+A_{10}X^4+A_{11}X^3+A_{12}X^2+A_{13}X+A_{14}$$

d. If N3 = 4, Gauss Quadrature for two dimensions.

A(1) = Lower bound of X.

A(2) = Upper bound of X.

A(3) = Lower bound of Y.

A(4) = Upper bound of Y.

A(5) through A(20) are coefficients of CUPOL.

IV. LIMITATIONS

A. SIZE AND NUMBER OF MATRICES

The storage available for all of the matrices in any problem is 80,000 bytes or 10,000 double words. This limit is arbitrary and controlled only by the total core storage available at any installation. For the naval Postgraduate School installation, 10,000 double words was selected in order to reduce turn around time in batch processing and reduce the size of the data set required for time sharing. The total number of matrices which can be stored is 100.

B. MATRIX NAMES

Each matrix is referred to by its name composed of one to six alphameric characters including blanks. The name is selected by the user when the matrix is first loaded or generated by an operation. If the name for a previously defined matrix is used later as a name of a new matrix, the former matrix is deleted before the operation is executed and is replaced by the new matrix. This is done so that there is only one matrix with a certain name at any one time.

C. PLOT

There are 200 points in the Y direction on the graph. The X direction has 130 points for the remote terminal printing and 160 points for the offline printer. The difference is due to the different number of lines per inch. The accuracy of the position of a point depends on the range in both the X and Y direction. The maximum error in the Y direction is the range of Y divided by 200. The maximum error in the X direction is

the range of X divided by either 130 for the remote terminal or 160 for the offline printer. If the X and Y ordinates of two or more points fall on the same nodal point on the graph, only one point will be plotted. If the points are from different matrices, the matrix hierarchy (see page 34) determines which will be plotted.

D. INTEGRATION

Integration by Simpson's Rule is restricted to equally spaced points in any one direction. The error is of the order of H_x^2 for integration in one dimension and of the order of H_x^2 times H_y^2 for two dimensions. H_x does not have to equal H_y but there has to be an odd number of points in any one direction. Integration by Gauss Quadrature for six Gauss ordinates is exact for all polynomials of degree eleven or less in one dimension and for CUPOL in two dimensions [Ref. 11]

E. POLFIT AND CONTUR

The polynomial, CUPOL, will pass through the values of the function at the nodal points of the grid but may not be a true representation in the space between nodal points. If the range of values of the function is less than 10^{-9}, a contour map will not be printed.

V. HOW TO CALL THE MATRIX INTERPRETIVE SYSTEM

A. TIME SHARING (IMIS VERSION)

At the Naval Postgraduate School, IMIS is stored in a library (AED) with the name, LIT, so that any number of users can use the system at any one time. In order to call LIT, it must be called as a subroutine. A Fortran program called IMIS has to be written as follows:

```
CALL LIT
STOP
END
```

There are two other libraries which must be loaded along with AED library in order to use LIT. This can be done with an executive program called SMIS as follows:

```
FORTRAN IMIS
GLOBAL LOADER TXTLIB AEDLIB SYSLIB
LOAD IMIS
START
```

SMIS is then executed with the command, $ SMIS. The computer will then type out the executive program with each command preceded by a time. Next it will type

EXECUTION BEGINS ...

At this time you are in IMIS and ready to begin the first problem. The first command will be START.

B. BATCH PROCESSING (DSMIS VERSION)

The first card must be a job card for the batch processing system as follows:

//aaaznnnn$_b$JOB(nnnn,ssssFP,TTTT), 'IDENTIFICATION'

where

aaa = The first three letters of the user's last name.

z = Job sequence number

nnnn= User's number.

ssss= Project number.

TTTT= Student section or faculty number.

The next six cards are control cards. Card five is used only when using the punch command. The cards are as follows stating in column one:

//JOBLIB$_b$DD$_b$DSNAME=DSMIS.F59CI,UNIT=2314,DISP=(OLD,KEEP),

//$_{bbbbbbbbbbbb}$VOLUME=SER=MARY

//$_{bb}$EXEC$_b$PGM=DSMIS,REGION=160K

//FT06F001$_b$DD$_b$SYSOUT=A

//FT07F001$_b$DD$_b$SYSOUT=B

//FT05F001$_b$DD$_b$*

The "$_b$" is where blanks are left.

The problem deck follows with the first command a START command and the last a STOP command. The last card of the deck is a standard delimiter card:

/*

On the job request card, check the item marked DISK PACK under the SPECIAL INPUT heading and write in "MARY". If the punch command is being used, under the heading SPECIAL OUTPUT check the item marked PUNCHED CARDS.

VI. SAMPLE PROBLEMS

A. THE EIGEN SYSTEM

The matrix equation

$$[A]\ \{X\} = \lambda [B]\ \{X\}$$

where

$$[A] = \begin{bmatrix} 0.0 & -1.0 & 0.0 \\ -1.0 & 2.0 & -1.0 \\ 0.0 & -1.0 & 2.0 \end{bmatrix}$$

and

$$[B] = \begin{bmatrix} 1.5 & 0.0 & 0.0 \\ 0.0 & 2.0 & 0.0 \\ 0.0 & 0.0 & 2.5 \end{bmatrix}$$

is to be solved. The entire sequence of events is as shown below. Everything written in lower case was typed by the operator. The computer response is in upper case.

```
start

    START
load  a                           3     3
    LOAD  A
    3 ROWS,     3 COLUMNS
0.0   -1.0   0.0  -1.0  2.0   -1.0  0.0   -1.0   2.0
load  b                           1     3
    LOAD  B
    1 ROWS,     3 COLUMNS
1.5   2.0   2.5
eigen a     b     c     d         3     1
    EIGEN A     B     C     D
    3
print c
    PRINT C


            1             2             3
      1  -3.774271D-01 1.136139D 00-8.056459D-01
      2  -4.626117D-01 5.490667D-01 1.329088D 00
      3   1.069364D 00 6.385240D-01 2.906204D-01


print d
    PRINT D


            1             2             3
      1   1.505111D 00 5.934423D-01-2.985532D-01
```

```
trans c      ct
    TRANS C      CT
zero  x
    ZERO  X
    3 ROWS,      3 COLUMNS
stodg x      d
    STODG X      D
mult  ct     x      ctx
    MULT  CT     X      CTX
mult  ctx    c      a
    MULT  CTX    C      A
print a
    PRINT A


               1             2             3
       1  -1.471323D-13-1.000000D 00 1.902783D-13
       2  -1.000000D 00 2.000000D 00-1.000000D 00
       3   1.902228D-13-1.000000D 00 2.000000D 00


stop
    STOP
```

B. CONTOUR MAP

A contour map for a surface described by the ordinates at the sixteen nodal points of the grid shown on page 47 is desired.

$$[A] = \begin{bmatrix} 10.0 & 12.0 & 8.0 & 10.0 \\ 12.0 & 11.0 & 9.0 & 8.0 \\ 8.0 & 9.0 & 11.0 & 12.0 \\ 10.0 & 8.0 & 12.0 & 10.0 \end{bmatrix}$$

and

$H_x = H_y = 1$

The results are as follows:

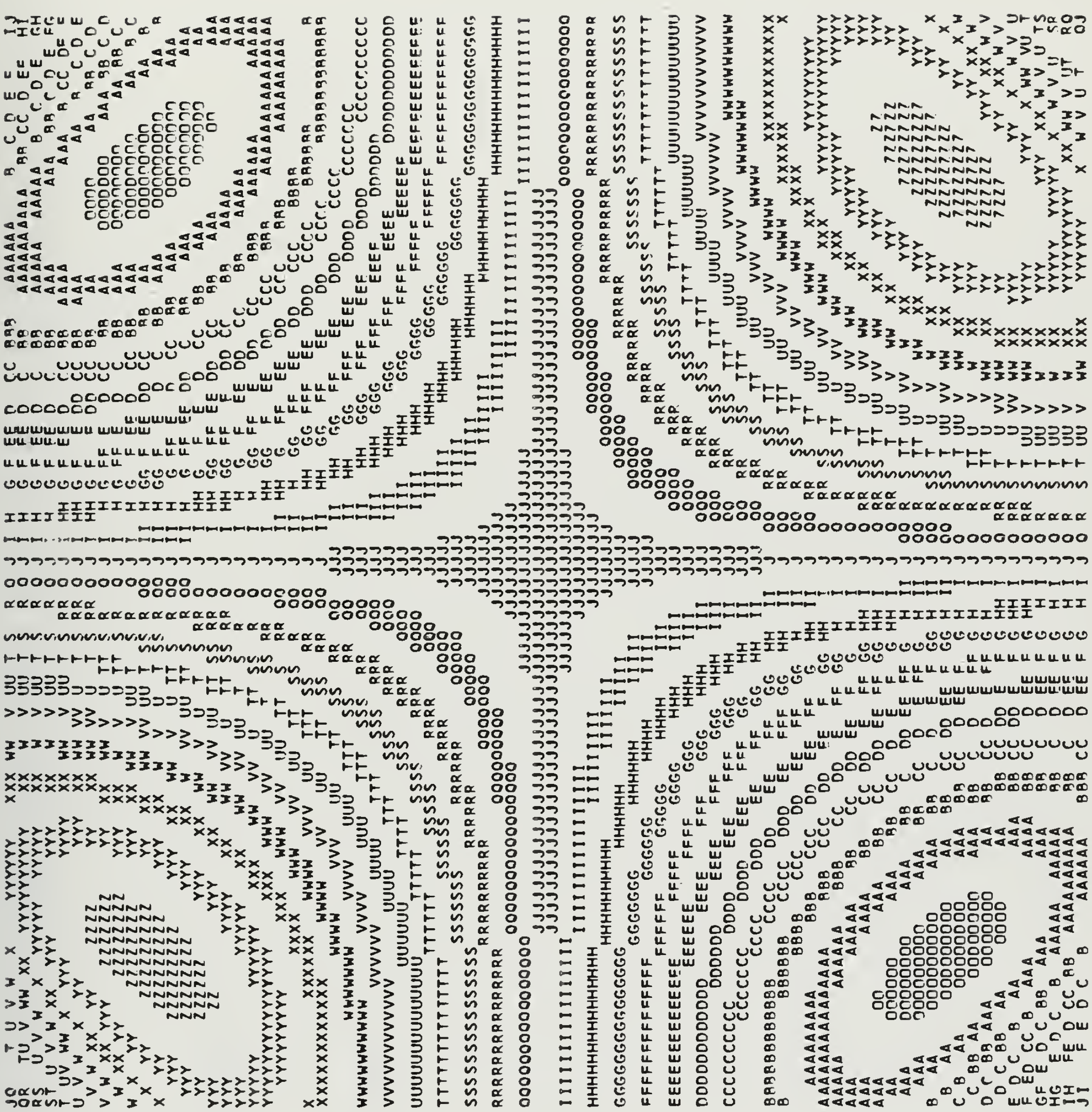
```
start

    START
load  a                                   18    1
    LOAD  A
   18 ROWS,     1 COLUMNS
1.    1.    10.   12.   8.    10.   12.    11.  9.     8.   8.     9.
11.   12.   10.   8.    12.   10.

contura     b
    CONTURA     B
```

THIS IS THE FIRST PAGE OUTPUT USING GRID POINTS AS INPUT.

```
U1-------U2--------U3--------U4
|        |         |         |
|        |         |         |
|        |         |         |
U5-------U6--------U7--------U8
|        |         |         |
|        |         |         |
|        |         |         |
U9-------U10-------U11-------U12
|        |         |         |
|        |         |         |
|        |         |         |
U13------U14-------U15-------U16
```

```
U1 =   10.000000 U2 =   12.000000 U3 =    8.000000 U4 =   10.000000
U5 =   12.000000 U6 =   11.000000 U7 =    9.000000 U8 =    8.000000
U9 =    8.000000 U10=    9.000000 U11=   11.000000 U12=   12.000000
U13=   10.000000 U14=    8.000000 U15=   12.000000 U16=   10.000000
```

```
O=   7.0814463545      RANGE(   0.708145D 01         0.129186D 02 )
A=        7.3733   B=        7.6652   C=        7.9570   D=        8.2489   E=        8.5407
F=        8.8326   G=        9.1244   H=        9.4163   I=        9.7081   J=       10.0000
Q=       10.2919   R=       10.5837   S=       10.8756   T=       11.1674   U=       11.4593
V=       11.7511   W=       12.0430   X=       12.3348   Y=       12.6267   Z=       12.9186
```



```
punch b
    PUNCH B
(4f15.8)


stop
    STOP
```

The command

offline punch file ft07f001

will cause the matrix B to be punched onto cards with the indicated format of four numbers per card with a field width of 15 and 8 significant figures.

If the input for the contour map had been the coefficients of CUPOL, the first page of output would have been as follows:

```
THIS IS THE FIRST PAGE OUTPUT COEFFICIENTS AS INPUT.


  -0.333300 X3Y3     1.500000 X3Y2    -2.833000 X3Y      2.000000 X3
   1.500000 X2Y3    -6.750000 X2Y2    12.750000 X2Y     -9.000000 X2
  -2.833000 XY3     12.750000 XY2    -18.750000 XY       9.000000 X
   2.000000 Y3      -9.000000 Y2       9.000000 Y       10.000000
```

```
O=    7.0837699378        RANGE(   0.708377D 01          0.129594D 02 )
A=        7.3776    B=        7.6713    C=        7.9651    D=        8.2589    E=        8.5527
F=        8.8465    G=        9.1402    H=        9.4340    I=        9.7278    J=       10.0216
Q=       10.3154    R=       10.6092    S=       10.9029    T=       11.1967    U=       11.4905
V=       11.7843    W=       12.0781    X=       12.3719    Y=       12.6656    Z=       12.9594
```

C. GRAPH

A plot of the function

$$x = e^{-15t} \sin(54.99t)$$

is desired from t = 0.0 to t = 0.3. The values were calculated in a separate program and the values of X were punched onto cards. They were prepared for offline reading into file FT04F001.

The first card is a standard CP67 offline read card as follows starting in column one.

$CP67USERID_{bb}GUxxssss_{bbbbbb}TTTT$

where

xx = Terminal number user will be using.

ssss= User's account number.

TTTT= User's name.

The second card is as follows:

$OFFLINE_{b}READ_{b}FILE_{b}FT04F001$

The next card is a LOAD command card with a 1. in S1.

```
LOAD A                  80   2                        1.
```

The matrix is punched onto cards row-wise with the same format as one of the options under IMIS and these cards follow the LOAD card. As many matrices as desired may be loaded in this manner. The last card is a continue card as follows:

```
CONT                                                  1.
```

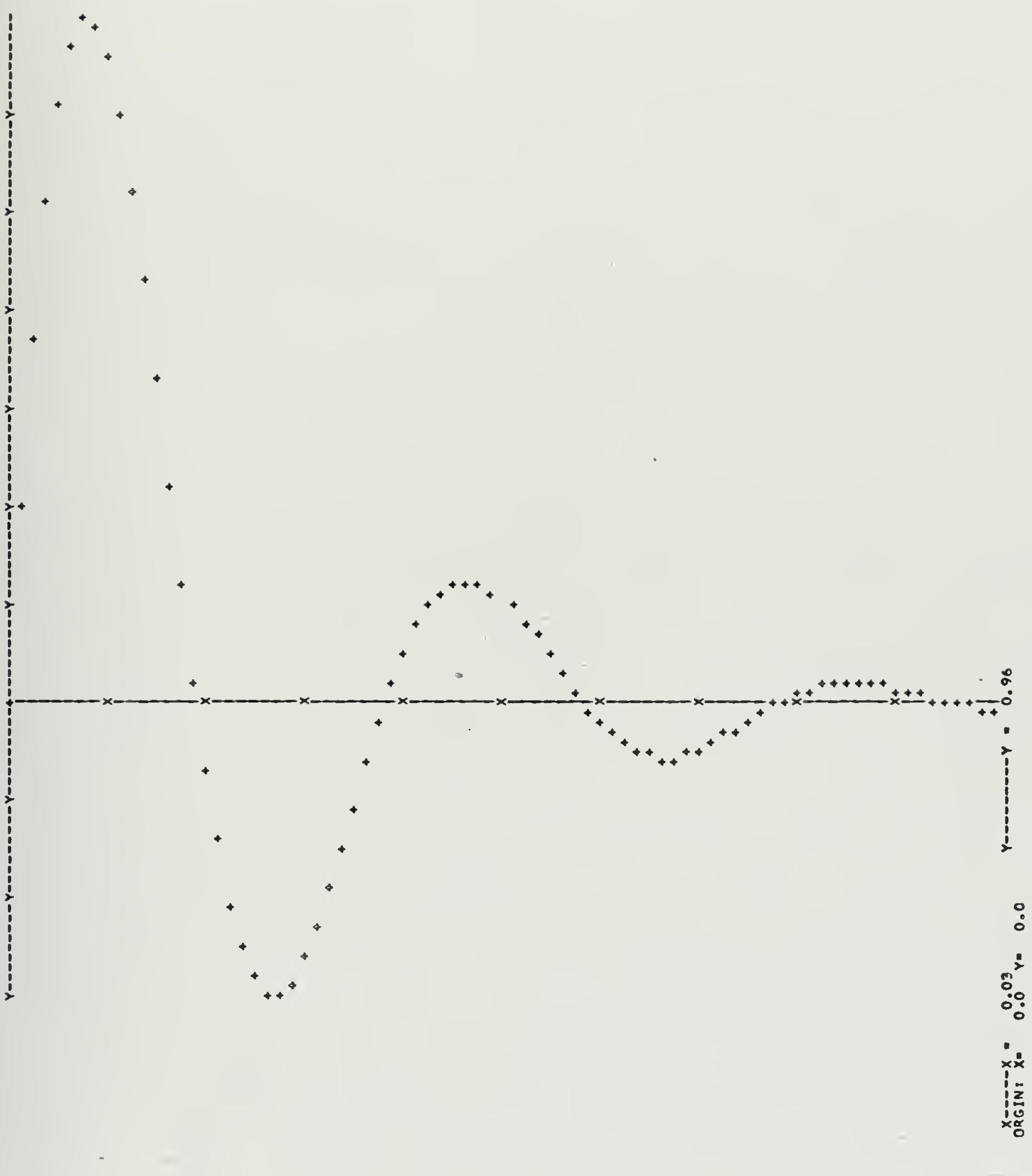
This card indicates that all matrices have been read from file FT04F001. The deck is then loaded into the computer.

After logging onto the time sharing system, the command to read the file is as follows:

```
offline read *
   OFFLINE READ READ FILE FT04F001
```

IMIS is then executed and the sequence is as follows:

```
start

    START
read


    LOAD  A
   80 ROWS,      2 COLUMNS
write a                            1
    WRITE A
plot  a
    PLOT  A
```


X-----X = 0.03
ORGIN: X= 0.0 Y= 0.0
Y---------Y = 0.96

$stop_{STOP}$

The command

```
OFFLINE PRINTCC FILE FT08F001
```

will cause the matrix A to be printed on the offline printer.

VII. IMPROVEMENTS

This system is an open ended system, i.e., any matrix operation with fewer than four matrix arguments, four integer arguments and two scalar arguments can be coded as a new command and added to the system. As coded this program is sequential. Each command is executed once after it is read, no facilities for automatic repetitive execution of one or more commands is included. Such a feature would be very useful if it could be implemented without introducing extraneous complexities to the language.

APPENDIX A COMPUTER PROGRAM

```
C     MAIN PROGRAM                                                        LIT00010
      IMPLICIT REAL*8(A-H,O-Z)                                            LIT00020
      COMMON      XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)         LIT00030
     1          ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)      LIT00040
     2,NN(100),NW1(80)                                                    LIT00050
C                                                                         LIT00060
C     INITIALIZATION                                                      LIT00070
C                                                                         LIT00080
      NSIZE=4                                                             LIT00090
      WRITE (6,99)                                                        LIT00100
      NUM=0                                                               LIT00110
      CALL SMIS1                                                          LIT00120
   99 FORMAT (1H1 )                                                       LIT00130
      STOP 1                                                              LIT00140
      END                                                                 LIT00150


      SUBROUTINE MLIST(MM,*)                                              LIT00160
      IMPLICIT REAL*8(A-H,O-Z)                                            LIT00170
C                                                                         LIT00180
C     SUBROUTINE TO LIST MATRIX                                           LIT00190
C                                                                         LIT00200
      REAL*8 NAME,MM                                                      LIT00210
      COMMON       NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)         LIT00220
     1          ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)      LIT00230
     2,NN(100),NW1(80)                                                    LIT00240
      I=1                                                                 LIT00250
   15 IF (NUM-I) 30,10,10                                                 LIT00260
   10 IF (NAME(I)-MM) 20,25,20                                            LIT00270
   20 I=I+1                                                               LIT00280
      GO TO 15                                                            LIT00290
   25 CALL DELETE(MM,&5)                                                  LIT00300
   30 NUM=NUM+1                                                           LIT00310
      NROW(NUM)=NR                                                        LIT00320
      NCOL(NUM)=NC                                                        LIT00330
      NAME(NUM)=MM                                                        LIT00340
      NN(NUM)=NSIZE                                                       LIT00350
      NX=NSIZE                                                            LIT00360
      NSIZE=NSIZE+NR*NC                                                   LIT00370
      IF (NUM-101) 45,40,45                                               LIT00380
   40 CALL ERRER(6,&5)                                                    LIT00390
   45 IF(10001-NSIZE) 50,60,60                                            LIT00400
   50 CALL ERRER(5,&5)                                                    LIT00410
   60 RETURN                                                              LIT00420
    5 RETURN 1                                                            LIT00430
      END                                                                 LIT00440
```

```
      SUBROUTINE SMIS1
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON      XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)
     1           ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)
     2,NN(100),NW1(80)
      REAL*8 NOPER,NSTART,LISTOP
      DIMENSION OPLIST(50),LISTOP(50),HED(10),FMT(10)
      EQUIVALENCE (OPLIST(1),LISTOP(1)),(OPER,NOPER),(NSTART,START)
C
C     LIST OF OPERATIONS
C
      DATA OPLIST/8HZZZZZZZ  ,8HPRINT   ,8HZERO    ,8HDELETE  ,8HDUPL
     1,8HADD     ,8HSUB     ,8HSCALE   ,8HMULT    ,8HINVERT  ,8HTRANS
     2,8HSTOSM   ,8HRMVSM   ,8HWRITE   ,8HREAD    ,8HSTART   ,8HREWIND
     3,8HEIGEN   ,8HRESPON  ,8HFUNGN   ,8HSQREL   ,8HINVEL   ,8HSTOP
     4,8HENVEL   ,8HADDSM   ,8HREMARK  ,8HSYMINV  ,8HFORMK   ,8HLOG
     5,8HSTODG   ,8HRMVDG   ,8HMSCALE  ,8HLOAD    ,8HCONT    ,8HPLOT
     6,8HITGRAL  ,8HCONTUR  ,8HPOLFIT  ,8HPUNCH   /,START/8HSTART   /,
     7XZR/8H         /
    9 CONTINUE
      OPER=XZR
      XA=XZR
      XB=XZR
      XC=XZR
      XD=XZR
      DO 1 I=1,80
      W1(I)=0.0D0
      W2(I)=0.0D0
      W3(I)=0.0D0
      W4(I)=0.0D0
    1 NW1(I)=0
      DO 2 I=1,10000
    2 A(I)=0.0D0
      DO 3 I=1,100
      NROW(I)=0
      NCOL(I)=0
      NN(I)=0
C
C     READ AND PRINT OF CONTROL INFORMATION
C
    3 XNAME(I)=XZR
      NUMOP=39
    4 CONTINUE
    5 READ(5,101)  OPER,XA,XB,XC,XD,NR,NC,NNR,NNC,SCAL1,SCAL2
      IF (NSTART-NOPER) 7,6,7
   27 READ(4,101) OPER,XA,XB,XC,XD,NR,NC,NNR,NNC,SCAL1,SCAL2
      IF(SCAL1-1.0) 28,6,28
   28 CALL ERRER(10,&5)
```

```
    6 WRITE(6,99)
    7 WRITE(6,100) OPER,XA,XB,XC,XD
C
C       DETERMINATION OF OPERATION
C
        I=1
   10 IF(NUMOP-I) 20,30,30
   20 CALL ERRER(3,&5)
   30 IF (LISTOP(I)-NOPER) 40,50,40
   40 I=I+1
      GO TO 10
   50 GO TO ( 20,120,130,140,150,160,170,180,190,200,210,220,230,240,
     1  250,260,270,280,290,300,310,320,330,340,350,360,370,380,390,
     2  400,410,420,430,440,450,460,470,480,490),I
C
C       MATRIX LOAD
C
  430 WRITE(6,102) NR,NC
      CALL MLIST(XA,&5)
      NA=NX
      CALL LOAD(A(NA),NR,NC,NNR,SCAL1,&5)
      IF(SCAL1.EQ.1.0) GO TO 27
      GO TO 5
C
C        CONTINUE OPERATION
C
  440 GO TO 5
C
C       MATRIX PRINT
C
  120 IF(XB.EQ.1.0D0) WRITE(6,99)
  123 WRITE(6,109)
      K=1
      GO TO 361
  121 CALL MFIND(XA,&5)
  126 NA=NX
      CALL APRINT(A(NA),NR,NC,NNR)
      WRITE(6,109)
      GO TO 5
C
C       MATRIX ZERO
C
  130 WRITE(6,102) NR,NC
      CALL MLIST(XA,&5)
      DO 135 I=NX,NSIZE
  135 A(I)=0.0D0
      GO TO 5
C
```

```
C       DELETE OPERATION
C
  140 CALL DELETE(XA,&5)
      GO TO 5
C
C       DUPLICATION OF MATRIX
C
  150 CALL MFIND(XA,&5)
      CALL MLIST(XB,&5)
      NB=NX-1
      CALL MFIND(XA,&5)
      NA=NX-1
      NS=NR*NC
      DO 155 I=1,NS
      J=I+NB
      K=I+NA
  155 A(J)=A(K)
      GO TO 5
C
C       ADDITION OR SUBTRACTION OF MATRICES
C
  160 TAG=1.0
      GO TO 171
  170 TAG=-1.0
  171 CALL MFIND(XA,&5)
      NA=NX-1
      NNR=NR
      NNC=NC
      CALL MFIND(XB,&5)
      NB=NX-1
      IF(NR-NNR) 173,172,173
  172 IF(NC-NNC) 173,174,173
  173 CALL ERRER(1,&5)
  174 NS=NR*NC
  175 DO 176 I=1,NS
      J=I+NA
      K=I+NB
  176 A(J)=A(J)+TAG*A(K)
      GO TO 5
C
C       SCALAR MULTIPLICATION
C
  180 WRITE(6,103) SCAL1
      CALL MFIND(XA,&5)
      NA=NX
      NB=NX-1+NR*NC
      DO 185 I=NA,NB
  185 A(I)=SCAL1*A(I)
```

```
      GO TO 5                                                           LIT01890
C                                                                       LIT01900
C     MATRIX MULTIPLICATION                                             LIT01910
C                                                                       LIT01920
  190 CALL MFIND(XA,&5)                                                 LIT01930
      NRA=NR                                                            LIT01940
      NCA=NC                                                            LIT01950
      CALL MFIND(XB,&5)                                                 LIT01960
      NRB=NR                                                            LIT01970
      NCB=NC                                                            LIT01980
      IF(NCA-NRB) 191,192,191                                           LIT01990
  191 CALL ERRER(1,&5)                                                  LIT02000
  192 NR=NRA                                                            LIT02010
      CALL MLIST(XC,&5)                                                 LIT02020
      ND=NX                                                             LIT02030
      CALL MFIND(XA,&5)                                                 LIT02040
      NA=NX                                                             LIT02050
      CALL MFIND(XB,&5)                                                 LIT02060
      NB=NX                                                             LIT02070
      CALL MULT(NRA,A(NA),NCA,A(NB),NCB,A(ND))                          LIT02080
      GO TO 5                                                           LIT02090
C                                                                       LIT02100
C     MATRIX INVERSION                                                  LIT02110
C                                                                       LIT02120
  200 CALL MFIND(XA,&5)                                                 LIT02130
      NA=NX                                                             LIT02140
      IF(NR-NC) 201,202,201                                             LIT02150
  201 CALL ERRER(1,&5)                                                  LIT02160
  202 CALL INVERT(A(NA),W3(1),NW1(1),NR)                                LIT02170
      GO TO 5                                                           LIT02180
C                                                                       LIT02190
C     MATRIX TRANSPOSE                                                  LIT02200
C                                                                       LIT02210
  210 CALL MFIND(XA,&5)                                                 LIT02220
      NRA=NR                                                            LIT02230
      NR=NC                                                             LIT02240
      NC=NRA                                                            LIT02250
      CALL MLIST(XB,&5)                                                 LIT02260
      NB=NX                                                             LIT02270
      CALL MFIND(XA,&5)                                                 LIT02280
      NA=NX                                                             LIT02290
      CALL TRANS(A(NA),A(NB),NRA,NC)                                    LIT02300
      GO TO 5                                                           LIT02310
C                                                                       LIT02320
C     STORE SUBMATRIX                                                   LIT02330
C                                                                       LIT02340
  220 NTAG=1                                                            LIT02350
  221 J=NR                                                              LIT02360
```

```
      K=NC
      CALL MFIND(XB,&5)
      GO TO 235
C
C     REMOVE SUBMATRIX
C
  230 J=NR
      K=NC
      NR=NNR
      NC=NNC
      WRITE(6,102) NR,NC
      NTAG=0
      CALL MLIST(XB,&5)
  235 WRITE(6,104) J,K
      NB=NX
      NRB=NR
      NCB=NC
      CALL MFIND(XA,&5)
      NA=NX
      NRA=NR
      NCA=NC
      CALL STOSM(A(NA),A(NB),NRA,NCA,NRB,NCB,J,K,NTAG)
      GO TO 5
C
C     WRITE MATRIX IN FILE FT08F001
C
  240 IF(NNR-1) 122,124,122
  122 CALL ERRER(11,&5)
  124 WRITE(8,111) XA
      GO TO 123
C
C     READ MATRIX FROM FILE FT04F001
C
  250 GO TO 27
C
C     START
C
  260 NSIZE=4
      NUM=0
      GO TO 9
C
C     REWIND TAPE NR
C
  270 CALL ERRER(9,&5)
C
C     EIGENVALUES AND EIGENVECTORS
C
  280 M=NR
```

```
      N2=NC
      CALL MFIND(XA,&5)
      IF (NR-NC) 281,282,281
  281 CALL ERRER(1,&5)
  282 N=NR
      NEV=N
      NR=1
      CALL MLIST(XD,&5)
      NR=IABS (M)
      CALL MLIST(XC,&5)
      NE=NX
      CALL MFIND(XA,&5)
      NA=NX
      CALL MFIND(XB,&5)
      NB=NX
      CALL MFIND(XD,&5)
      ND=NX
      WRITE(6,107) M
      CALL EIG(A(NA),A(NB),A(NE),A(ND),NEV,M,N2,N)
      GO TO 5
C
C     RESPONSE CALCULATION
C
  290 N=NR
      WRITE(6,107) N,SCAL1,SCAL2
      CALL MFIND(XA,&5)
      M=NC
      CALL MFIND(XC,&5)
      NC=NC/N
      NR=M
      CALL MLIST(XD,&5)
      ND=NX
      CALL MFIND(XA,&5)
      NA=NX
      CALL MFIND(XB,&5)
      NB=NX
      CALL MFIND(XC,&5)
      NNC=NX
      NTAG=1
      IF(NR-1) 396,394,396
  394 NTAG=0
  396 L=NC
      CALL RESPON(A(NA),A(NB),A(NNC),A(ND),M,N,L,SCAL1,SCAL2,NTAG)
      GO TO 5
C
C     FUNCTION GENERATION
C
  300 N=NR
```

```
      WRITE(6,107) N,SCAL1
      NR=1
      NC=N
      CALL MLIST(XB,&5)
      K=NX
      NH=NX+N-1
      CALL MFIND(XA,&5)
      L=NX
      TIM =A(L)
      GO TO 302
  301 IF (A(L)-TIM) 302,302,306
  302 DT=A(L+2)-A(L)
      DP=A(L+3)-A(L+1)
      L=L+2
      IF (DT) 304,302,305
  304 CALL ERRER(1,&5)
  305 SLOPE=DP/DT
  306 A(K)=A(L-1)+(TIM -A(L-2))*SLOPE
  308 TIM =TIM +SCAL1
      K=K+1
        IF (NH-K) 5,301,301
C
C     SQUARE ROOT OF EACH ELEMENT
C
  310 CALL MFIND(XA,&5)
      NA=NX
      NB=NA+NR*NC-1
      DO 315 K=NA,NB
  315 A(K)=DSQRT(A(K))
      GO TO 5
C
C     INVERSION OF EACH ELEMENT
C
  320 CALL MFIND(XA,&5)
      NA=NX
      NB=NA+NR*NC-1
      DO 325 K=NA,NB
  325 A(K)=1./A(K)
      GO TO 5
  330 RETURN
C
C     ENVELOPE VALUES OF MATRIX
C
  340 WRITE(6,101) XB
      K=2
      GO TO 361
  341 CALL MFIND(XA,&5)
      NA=NX
```

```
      NR=NR                                                             LIT03810
      NC=NC                                                             LIT03820
      K=NA                                                              LIT03830
      DO 347 I=1,NR                                                     LIT03840
      AMAX=0.0                                                          LIT03850
      TIM =SCAL1                                                        LIT03860
      DO 346 J=1,NC                                                     LIT03870
      XA=DABS(A(K))                                                     LIT03880
      IF(AMAX-XA) 344,345,345                                           LIT03890
  344 AMAX=XA                                                           LIT03900
      TMAX=TIM                                                          LIT03910
  345 K=K+1                                                             LIT03920
  346 TIM =TIM +SCAL1                                                   LIT03930
  347 WRITE(6,108) I,TMAX,AMAX                                          LIT03940
       WRITE(6,101) XB                                                  LIT03950
      GO TO 5                                                           LIT03960
C                                                                       LIT03970
C     ADD SUBMATRIX                                                     LIT03980
C                                                                       LIT03990
  350 NTAG=-1                                                           LIT04000
      GO TO 221                                                         LIT04010
C                                                                       LIT04020
C     READ AND PRINT OF REMARK CARDS                                    LIT04030
C                                                                       LIT04040
  360 K=3                                                               LIT04050
  361 IF(NR) 366,366,364                                                LIT04060
  364 IF(NNR.EQ.1) GO TO 367                                            LIT04070
      DO 365 I=1,NR                                                     LIT04080
      READ(5,105) HED                                                   LIT04090
  365 WRITE(6,110) HED                                                  LIT04100
  366 GO TO (121,341,5),K                                               LIT04110
  367 DO 368 I=1,NR                                                     LIT04120
      READ(5,105) HED                                                   LIT04130
  368 WRITE(8,110) HED                                                  LIT04140
      GO TO 366                                                         LIT04150
C                                                                       LIT04160
C     INVERSION OF SYMMETRICAL MATRIX                                   LIT04170
C                                                                       LIT04180
  370 CALL MFIND(XA,&5)                                                 LIT04190
      NA=NX                                                             LIT04200
      IF (NR-NC) 372,375,372                                            LIT04210
  372 CALL ERRER(1,&5)                                                  LIT04220
  375 CALL SYMINV(A(NA),NR,W1(1),W3(1))                                 LIT04230
      GO TO 5                                                           LIT04240
C                                                                       LIT04250
C     FORM 2X2 MATRIX                                                   LIT04260
C                                                                       LIT04270
  380 NR=2                                                              LIT04280
```

```
      NC=2                                                              LIT04290
      CALL MLIST(XA,&5)                                                 LIT04300
      NA=NX                                                             LIT04310
      CALL FORMK(A(NA))                                                 LIT04320
      GO TO 5                                                           LIT04330
C                                                                       LIT04340
C     TAKES A LOG OF A MATRIX                                           LIT04350
C                                                                       LIT04360
  390 CALL MFIND(XA,&5)                                                 LIT04370
      IH=NX-1+NR*NC                                                     LIT04380
      IL=NX                                                             LIT04390
      DO 395 I=IL,IH                                                    LIT04400
  395 A(I)= DLOG(A(I))                                                  LIT04410
      GO TO 5                                                           LIT04420
C                                                                       LIT04430
C     STORES ROW (B) ON DIAGONAL OF (A)                                 LIT04440
C                                                                       LIT04450
  400 CALL MFIND(XA,&5)                                                 LIT04460
      K=NX                                                              LIT04470
      CALL MFIND(XB,&5)                                                 LIT04480
      IL=NX                                                             LIT04490
      IH=NX-1+NC                                                        LIT04500
      DO 405 I=IL,IH                                                    LIT04510
      A(K)=A(I)                                                         LIT04520
  405 K=K+NC+1                                                          LIT04530
      GO TO 5                                                           LIT04540
C                                                                       LIT04550
C     REMOVES ROW (B) FROM DIAGONAL OF (A)                              LIT04560
C                                                                       LIT04570
  410 CALL MFIND(XA,&5)                                                 LIT04580
      NR=1                                                              LIT04590
      CALL MLIST(XB,&5)                                                 LIT04600
      IL=NX                                                             LIT04610
      IH=NX-1+NC                                                        LIT04620
      CALL MFIND(XA,&5)                                                 LIT04630
      K=NX                                                              LIT04640
      DO 415 I=IL,IH                                                    LIT04650
      A(I)=A(K)                                                         LIT04660
  415 K=K+NC+1                                                          LIT04670
      GO TO 5                                                           LIT04680
C                                                                       LIT04690
C     MULTIPLIES A BY B(1,1)                                            LIT04700
C                                                                       LIT04710
  420 CALL MFIND(XB,&5)                                                 LIT04720
      I=NX                                                              LIT04730
      SCAL1=A(I)                                                        LIT04740
      GO TO 180                                                         LIT04750
C                                                                       LIT04760
```

```
C       PLOT OPERATION
C
  450 INR=NNR
      NAA=0.0
      NAB=0.0
      NAC=0.0
      NBA=0.0
      NBB=0.0
      NBC=0.0
      CALL MFIND(XA,&5)
      NA=NX
      NB=NA+NC*NR-1
      IF(XB.EQ.XZR) GO TO 451
      CALL MFIND(XB,&5)
      NAA=NX
      NBA=NAA+NC*NR-1
      IF(XC.EQ.XZR) GO TO 451
      CALL MFIND(XC,&5)
      NAB=NX
      NBB=NAB+NC*NR-1
      IF(XD.EQ.XZR) GO TO 451
      CALL MFIND(XD,&5)
      NAC=NX
      NBC=NAC+NC*NR-1
  451 CALL PLOT(NA,NB,NAA,NAB,NAC,NBA,NBB,NBC,INR)
      IF(NNC) 455,455,454
  454 IF(INR) 456,456,457
  456 DO 458 JJ=1,NNC
  458 READ(5,105) HED
      GO TO 5
  457 DO 459 JJ=1,NNC
      READ(5,105) HED
  459 WRITE(8,110) HED
  455 GO TO 5
C
C        INTEGRATION OPERATION
C
  460 CALL MFIND(XA,&5)
      NA=NX
      INR=NNR
      CALL ITGRAL(NA,INR)
      GO TO 5
C
C        CONTUR OPERATION
C
  470 NOC=NC
      IF(NNR.EQ.0) NNR=1
      IF(NNC.EQ.0) NNC=1
```

```
      NAR=NNR                                                          LIT05250
      NAC=NNC                                                          LIT05260
      IF(NOC.LT.1) GO TO 474                                           LIT05270
      DO 471 I=1,NOC                                                   LIT05280
      READ(5,105) HED                                                  LIT05290
      GO TO (471,472),NAC                                              LIT05300
  472 WRITE(8,110) HED                                                 LIT05310
  471 CONTINUE                                                         LIT05320
  474 CALL CONTUR(XA,XB,NAR,NAC,NOC)                                   LIT05330
      GO TO 5                                                          LIT05340
C                                                                      LIT05350
C       POLYNOMINAL FIT OPERATION                                      LIT05360
C                                                                      LIT05370
  480 CALL POLFIT(XA,XB,&5)                                            LIT05380
      GO TO 5                                                          LIT05390
C                                                                      LIT05400
C     PUNCH OPERATION                                                  LIT05410
C                                                                      LIT05420
  490 READ(5,105) FMT                                                  LIT05430
      IF(NR.EQ.0) GO TO 491                                            LIT05440
      DO 492 J=1,NR                                                    LIT05450
      READ(5,105) HED                                                  LIT05460
  492 WRITE(7,105) HED                                                 LIT05470
  491 CALL MFIND(XA,&5)                                                LIT05480
      NA=NX                                                            LIT05490
      NB=NA-1+NR*NC                                                    LIT05500
      WRITE(7,FMT) (A(I),I=NA,NB)                                      LIT05510
      GO TO 5                                                          LIT05520
   99 FORMAT (1H1 )                                                    LIT05530
  100 FORMAT(5X,5A6)                                                   LIT05540
  101 FORMAT(5A6,4I6,2F6.0)                                            LIT05550
  102 FORMAT (1I6,6H ROWS, 1I6, 8H COLUMNS )                           LIT05560
  103 FORMAT (9H  SCALAR= 1PD15.7)                                     LIT05570
  104 FORMAT (12H  ROW NUMBER I4,18H,    COLUMN NUMBER I4)             LIT05580
  105 FORMAT(10A8)                                                     LIT05590
  106 FORMAT (11H  TAPE UNIT  I3)                                      LIT05600
  107 FORMAT(1I6,2F12.5)                                               LIT05610
  108 FORMAT (1I6,1F15.5,1PD18.7)                                      LIT05620
  109 FORMAT(1H0)                                                      LIT05630
  110 FORMAT(2X,10A8)                                                  LIT05640
  111 FORMAT(10X,1A6)                                                  LIT05650
      END                                                              LIT05660
```

```
      SUBROUTINE APRINT( A ,NR,NC,NNR)                                  LIT05670
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT05680
      DIMENSION A(1),NCOL(8)                                            LIT05690
      DOUBLE PRECISION A                                                LIT05700
C                                                                       LIT05710
C     PRINT OPERATION                                                   LIT05720
C                                                                       LIT05730
      IF(NNR.EQ.1) GO TO 60                                             LIT05740
      DO 50 M=1,NC,8                                                    LIT05750
      NN=NC-M                                                           LIT05760
      IF (NN-7) 40,40,35                                                LIT05770
   35 NN=7                                                              LIT05780
   40 MM=NN+1                                                           LIT05790
      DO 45 N=1,MM                                                      LIT05800
   45 NCOL(N)=M-1+N                                                     LIT05810
      WRITE(6,101) (NCOL(N),N=1,MM)                                     LIT05820
      DO 50 N=1,NR                                                      LIT05830
      NL=M+(N-1)*NC                                                     LIT05840
      NH=NL+NN                                                          LIT05850
   50 WRITE(6,100) (N,(A(I),I=NL,NH))                                   LIT05860
      RETURN                                                            LIT05870
   60 DO 61 M=1,NC,8                                                    LIT05880
      NN=NC-M                                                           LIT05890
      IF(NN-7) 63,63,62                                                 LIT05900
   62 NN=7                                                              LIT05910
   63 MM=NN+1                                                           LIT05920
      DO 64 N=1,MM                                                      LIT05930
   64 NCOL(N)=M-1+N                                                     LIT05940
      WRITE(8,101) (NCOL(N),N=1,MM)                                     LIT05950
      DO 61 N=1,NR                                                      LIT05960
      NL=M+(N-1)*NC                                                     LIT05970
      NH=NL+NN                                                          LIT05980
   61 WRITE(8,100) (N,(A(I),I=NL,NH))                                   LIT05990
      WRITE(8,102)                                                      LIT06000
      RETURN                                                            LIT06010
  100 FORMAT(2X,1I6,2X,8(1PD13.6     ))                                 LIT06020
  101 FORMAT(1H0,2X,8I13)                                               LIT06030
  102 FORMAT(1H0)                                                       LIT06040
  103 FORMAT(T10,1A6)                                                   LIT06050
      END                                                               LIT06060

      SUBROUTINE ERRER(N,*)                                             LIT06070
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT06080
      REAL*8 NSTART,NOPER                                               LIT06090
      COMMON      XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)       LIT06100
     1           ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)   LIT06110
     2,NN(100),NW1(80)                                                  LIT06120
```

```
      GO TO (1,2,3,4,5,6,7,8,9,10,11),N                                 LIT06130
    1 WRITE(6,101)                                                      LIT06140
      GO TO 100                                                         LIT06150
    2 WRITE(6,102)                                                      LIT06160
      GO TO 100                                                         LIT06170
    3 WRITE(6,103)                                                      LIT06180
      GO TO 100                                                         LIT06190
    4 WRITE(6,104)                                                      LIT06200
      GO TO 100                                                         LIT06210
    5 WRITE(6,105)                                                      LIT06220
      GO TO 100                                                         LIT06230
    6 WRITE(6,106)                                                      LIT06240
      GO TO 100                                                         LIT06250
    7 WRITE(6,107)                                                      LIT06260
      GO TO 100                                                         LIT06270
    8 WRITE(6,108)                                                      LIT06280
      GO TO 100                                                         LIT06290
    9 WRITE(6,109)                                                      LIT06300
      GO TO 100                                                         LIT06310
                                                                        LIT06320
   10 WRITE(6,110)                                                      LIT06330
      GO TO 100                                                         LIT06340
   11 WRITE(6,111)                                                      LIT06350
  100 RETURN 1                                                          LIT06360
   50 FORMAT (1A6)                                                      LIT06370
   99 FORMAT(1H1,4X,6H START)                                           LIT06380
  101 FORMAT (27H MATRICES INCOMPATIBLE      )                          LIT06390
  102 FORMAT (27H MATRIX UNDEFINED           )                          LIT06400
  103 FORMAT (27H OPERATION UNDEFINED        )                          LIT06410
  104 FORMAT (27H MATRIX PREVIOUSLY DEFINED  )                          LIT06420
  105 FORMAT (27H STORAGE EXCEEDED           )                          LIT06430
  106 FORMAT (27H OVER 100 MATRICES IN CORE  )                          LIT06440
  107 FORMAT(27H ERROR IN EIGEN SUBROUTINE    )                         LIT06450
  108 FORMAT(27H ERROR IN LOAD OPERATION    )                           LIT06460
  109 FORMAT (27H OPERATION NOT AVAILABLE   )                           LIT06470
  110 FORMAT (27H ERROR IN READ OPERATION   )                           LIT06480
  111 FORMAT (27H ERROR IN WRITE OPERATION  )                           LIT06490
      END                                                               LIT06500

      SUBROUTINE FORMK(A)                                               LIT06510
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT06520
      DIMENSION A(1)                                                    LIT06530
      DOUBLE PRECISION A                                                LIT06540
      READ(5,100) XI,XA,XL,XE                                           LIT06550
      WRITE(6,200) XI,XA,XL,XE                                          LIT06560
      B=14.4*XI/(XA*XL**2)                                              LIT06570
      S=2.*XE*XI/((1.+2.*B)*XL)                                         LIT06580
```

```
      A(1)=S*(2.+B)
      A(2)=S*(1.-B)
      A(3)=A(2)
      A(4)=A(1)
      RETURN
  100 FORMAT (4F12.1)
  200 FORMAT (3H I=F12.1,5H,  A=F12.1,5H,  L=F12.1,5H,  E=F12.1)
      END


      SUBROUTINE LOAD( A ,NR,NC,NFMT,SCAL1,*)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(1)
      DOUBLE PRECISION A
C
C     LOAD OPERATION
C
      IF(NFMT.GT.4) CALL ERRER(8,&5)
      NS=NR*NC
      IF(NFMT.EQ.0) NFMT=1
      IF(SCAL1.EQ.1.0)GO TO 14
      GO TO (10,11,12,13),NFMT
   10 READ(5,100) (A(I),I=1,NS)
      GO TO 15
   11 READ(5,101) (A(I),I=1,NS)
      GO TO 15
   12 READ(5,102) (A(I),I=1,NS)
   13 READ(5,103) (A(I),I=1,NS)
      GO TO 15
   14 GO TO(20,21,22,23),NFMT
   20 READ(4,100) (A(I),I=1,NS)
      GO TO 15
   21 READ(4,101) (A(I),I=1,NS)
      GO TO 15
   22 READ(4,102) (A(I),I=1,NS)
      GO TO 15
   23 READ(4,103) (A(I),I=1,NS)
   15 RETURN
    5 RETURN 1
  100 FORMAT (12F6.0)
  101 FORMAT(6F12.0)
  102 FORMAT(4F18.0)
  103 FORMAT(3F24.0)
      END
```

```
      SUBROUTINE MFIND(MM,*)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON          NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)
     1               ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)
     2,NN(100),NW1(80)
C
C     SUBROUTINE TO FIND LOCATION AND SIZE OF MATRIX XX
C
      REAL*8 NAME,MM
      I=1
   15 IF((NUM-I).LT.0) CALL ERRER(2,&5)
   10 IF ( NAME(I)-MM) 20,30,20
   20 I=I+1
      GO TO 15
   30 NR=NROW(I)
      NC=NCOL(I)
      NX=NN(I)
      RETURN
    5 RETURN 1
      END


      SUBROUTINE DELETE(MM,*)
      IMPLICIT REAL*8(A-H,O-Z)
C
C      SUBROUTINE TO DELETE MATRIX MM
C
      REAL*8 NAME,MM
      COMMON          NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)
     1               ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)
     2,NN(100),NW1(80)
      I=1
   15 IF (NUM-I) 40,10,10
   40 CALL ERRER(2,&5)
   10 IF ( NAME(I)-MM) 20,30,20
   20 I=I+1
      GO TO 15
   30 NX=NN(I)
      NUM=NUM-1
      NS=NROW(I)*NCOL(I)
      NSIZE=NSIZE-NS
      DO 50 J=I,NUM
      NAME(J)=NAME(J+1)
      NROW(J)=NROW(J+1)
      NCOL(J)=NCOL(J+1)
   50 NN(J)=NN(J+1)-NS
      DO 60 J=NX,NSIZE
      I=J+NS
```

```
 60 A(J)=A(I)
     RETURN
  5 RETURN 1
    END

    SUBROUTINE MULT(NRA,A,NCA,B,NCB,C)
    IMPLICIT REAL*8(A-H,O-Z)
    DIMENSION A(1),B(1),C(1)
    DOUBLE PRECISION A,B,C
C
C     MATRIX MULTIPLICATION
C
    K=1
    DO 200 I=1,NRA
    NN=(I-1)*NCA+1
    NH=NN-1+NCA
    DO 200 J=1,NCB
    MM=J
    C(K)=0.0D0
    DO 100 L=NN,NH
    C(K)=C(K)+A(L)*B(MM)
100 MM=MM+NCB
200 K=K+1
    RETURN
    END

    SUBROUTINE TRANS(A,B,NR,NC)
    IMPLICIT REAL*8(A-H,O-Z)
    DIMENSION A(1),B(1)
    DOUBLE PRECISION A,B
C
C    MATRIX TRANSPOSE
C
    K=1
    DO 100 I=1,NC
    L=I
    DO 100 J=1,NR
    B(K)=A(L)
    L=L+NC
100 K=K+1
    RETURN
    END
```

```
      SUBROUTINE INVERT(A,C,M,N)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION A(1),C(1),M(1)
      DOUBLE PRECISION A,C
C
C         GENERAL MATRIX INVERSION SUBROUTINE
C
      DO 90 I=1,N
   90 M(I)=-I
      DO 140 I=1,N
C
C     LOCATE LARGEST ELEMENT
C
      D=0.0D0
      DO 112 L=1,N
      IF (M(L)) 100,100,112
  100 J=L
      DO 110 K=1,N
      IF (M(K)) 103,103,108
  103 IF (DABS(D)-DABS(A(J))) 105,105,108
  105 LD=L
      KD=K
      D=A(J)
  108 J=J+N
  110 CONTINUE
  112 CONTINUE
C
C     INTERCHANGE COLUMNS
C
      TEMP=-M(LD)
      M(LD)=M(KD)
      M(KD)=TEMP
      L=LD
      K=KD
      DO 114 J=1,N
      C(J)=A(L)
      A(L)=A(K)
      A(K)=C(J)
      L=L+N
  114 K=K+N
C
C     DIVIDE ROW BY LARGEST ELEMENT
C
      NR=(KD-1)*N+1
      NH=NR+N-1
      DO 115 K=NR,NH
  115 A(K)=-A(K)/D
C
```

```
C     REDUCE REMAINING ROWS AND COLUMNS                                 LIT08350
C                                                                       LIT08360
      L=1                                                               LIT08370
      DO 135 J=1,N                                                      LIT08380
      IF (J-KD) 130,125,130                                             LIT08390
  125 L=L+N                                                             LIT08400
      GO TO 135                                                         LIT08410
  130 DO 134 K=NR,NH                                                    LIT08420
      A(L)=A(L)+C(J)*A(K)                                               LIT08430
  134 L=L+1                                                             LIT08440
  135 CONTINUE                                                          LIT08450
C                                                                       LIT08460
C     REDUCE COLUMN                                                     LIT08470
C                                                                       LIT08480
      C(KD)=1.0D0                                                       LIT08490
      J=KD                                                              LIT08500
      DO 140 K=1,N                                                      LIT08510
      A(J)=C(K)/D                                                       LIT08520
  140 J=J+N                                                             LIT08530
C                                                                       LIT08540
C     INTERCHANGE ROWS                                                  LIT08550
C                                                                       LIT08560
      DO 200 I=1,N                                                      LIT08570
      L=0                                                               LIT08580
  150 L=L+1                                                             LIT08590
      IF(M(L)-I) 150,160,150                                            LIT08600
  160 K=(L-1)*N+1                                                       LIT08610
      J=(I-1)*N+1                                                       LIT08620
      M(L)=M(I)                                                         LIT08630
      M(I)=I                                                            LIT08640
      DO 200 LL=1,N                                                     LIT08650
      TEMP=A(K)                                                         LIT08660
      A(K)=A(J)                                                         LIT08670
      A(J)=TEMP                                                         LIT08680
      J=J+1                                                             LIT08690
  200 K=K+1                                                             LIT08700
      RETURN                                                            LIT08710
      END                                                               LIT08720


      SUBROUTINE SYMINV(A,N,B,C)                                        LIT08730
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT08740
      DIMENSION A(1),B(1),C(1)                                          LIT08750
      DOUBLE PRECISION A,B,C                                            LIT08760
C                                                                       LIT08770
C      SYMMETRICAL MATRIX INVERSION                                     LIT08780
C                                                                       LIT08790
      LP=N                                                              LIT08800
```

```
      DO 10  I=2,LP                                                     LIT08810
      DO 10  J=I,LP                                                     LIT08820
      ICOL=J+LP*(I-2)                                                   LIT08830
      IROW=I+(J-1)*LP-1                                                 LIT08840
      IF(A(ICOL).NE.A(IROW))  WRITE(6,1000)                             LIT08850
      A(ICOL)=0.5D0*(A(ICOL)+A(IROW))                                   LIT08860
   10 A(IROW)=A(ICOL)                                                   LIT08870
 1000 FORMAT(/,54H *****************************************************LIT08880
     1       /,54H WARNING THE INPUT MATRIX TO SYMINV WAS NOT SYMMETRIC LIT08890
     2     /,54H **************************************************** ) LIT08900
      DO 140 I=1,N                                                      LIT08910
      NR=(I-1)*N                                                        LIT08920
      DO 100 J=1,N                                                      LIT08930
      K=NR+J                                                            LIT08940
  100 B(J)=A(K)                                                         LIT08950
      D=B(I)                                                            LIT08960
      DO 110 J=1,N                                                      LIT08970
  110 C(J)=-B(J)/D                                                      LIT08980
      L=1                                                               LIT08990
      DO 130 J=1,N                                                      LIT09000
      M=L                                                               LIT09010
      DO 120 K=J,N                                                      LIT09020
      A(L)=A(L)+B(J)*C(K)                                               LIT09030
      A(M)=A(L)                                                         LIT09040
      M=M+N                                                             LIT09050
  120 L=L+1                                                             LIT09060
  130 L=L+J                                                             LIT09070
      C(I)=-1.0D0/D                                                     LIT09080
      M=I                                                               LIT09090
      DO 140 J=1,N                                                      LIT09100
      K=NR+J                                                            LIT09110
      A(K)=C(J)                                                         LIT09120
      A(M)=C(J)                                                         LIT09130
  140 M=M+N                                                             LIT09140
      NS=N*N                                                            LIT09150
      DO 150 J=1,NS                                                     LIT09160
  150 A(J)=-A(J)                                                        LIT09170
      RETURN                                                            LIT09180
      END                                                               LIT09190


      SUBROUTINE STOSM(A,B,NRA,NCA,NRB,NCB,NR,NC,NTAG,*)                LIT09200
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT09210
      DIMENSION A(1),B(1)                                               LIT09220
      DOUBLE PRECISION A,B                                              LIT09230
C                                                                       LIT09240
C      SUBROUTINE TO STORE OR REMOVE A SUBMATRIX                        LIT09250
C                                                                       LIT09260
```

```
      IF (NRA+1-NR-NRB) 60,50,50
   50 IF (NCA+1-NC-NCB) 60,70,70
   60 CALL ERRER(1,&5)
   70 DO 100 I=1,NRB
      K=(NC-1)+(NR+I-2)*NCA
      L=(I-1)*NCB
      DO 100 J=1,NCB
      N=K+J
      M=L+J
      IF (NTAG) 75,90,80
   75 A(N)=A(N)+B(M)
      GO TO 100
   80 A(N)=B(M)
      GO TO 100
   90 B(M)=A(N)
  100 CONTINUE
      RETURN
    5 RETURN 1
      END


      SUBROUTINE RESPON(W,XM,P,X,NM,NT,L,DAMP,DT,NTAG)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION W(1),XM(1),P(1),X(1)
      DOUBLE PRECISION W,XM,P,X,DAMP,DT
C
C       RESPONSE PROGRAM
C
      K=1
      C1=DT/2.0D0
      C2=C1*DT/3.0D0
      C3=C2*2.0D0
      DO 160 N=1,NM
      NOUT=NT+1
      C4=W(N)**2
      C5=    DAMP*W(N)*2.0D0
      F=    C1*C5+C2*C4+1.0D0
      DISP=0.0D0
      VEL=0.0D0
      IL=L*(N-1)*NTAG+1
      ACEL=P(IL)*XM(N)
      IL=IL+1
      IH=IL+L-2
      DO 160 I=IL,IH
      A=VEL+C1*ACEL
      B=DISP+DT*VEL+C3*ACEL
      ACEL=(P(I)*XM(N)-C5*A-C4*B)/F
      VEL=A+C1*ACEL
```

```
      DISP=B+C2*ACEL                                                    LIT09730
      IF(NOUT-I) 160,150,160                                            LIT09740
  150 X(K)=DISP                                                         LIT09750
      K=K+1                                                             LIT09760
      NOUT=NOUT+NT                                                      LIT09770
  160 CONTINUE                                                          LIT09780
      RETURN                                                            LIT09790
      END                                                               LIT09800


      SUBROUTINE EIG(R,XM,V,E,NEV,M,N2,NM)                              LIT09810
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT09820
      DIMENSION R(1),XM(1),V(1),E(1)                                    LIT09830
      DOUBLE PRECISION R,XM,V,E                                         LIT09840
      LP=NM                                                             LIT09850
      IF(NM.EQ.1) RETURN                                                LIT09860
      NVEC=IABS(M)                                                      LIT09870
    1 DO 2 I=1,LP                                                       LIT09880
    2 XM(I)=1.0D0/(DSQRT(XM(I)))                                        LIT09890
      DO 3 I=1,LP                                                       LIT09900
      DO 3 J=1,LP                                                       LIT09910
      JJ=I+(J-1)*NM                                                     LIT09920
    3 R(JJ)=XM(I)*R(JJ)*XM(J)                                           LIT09930
      DO 104 I=2,LP                                                     LIT09940
      DO 104 J=I,LP                                                     LIT09950
      ICOL=J+LP*(I-2)                                                   LIT09960
      IROW=I+(J-1)*LP-1                                                 LIT09970
      IF(R(ICOL).NE.R(IROW))  WRITE(6,1000)                             LIT09980
      R(ICOL)=0.5D0*(R(ICOL)+R(IROW))                                   LIT09990
  104 R(IROW)=R(ICOL)                                                   LIT10000
 1000 FORMAT(/,54H *****************************************************LIT10010
     1      /,54H WARNING THE INPUT MATRIX TO EIGEN WAS NOT SYMMETRIC   LIT10020
     2    /,54H ***************************************************** ) LIT10030
      CALL JACVAT(R,NM,1,E,V,NM)                                        LIT10040
      NEL=NVEC*NM                                                       LIT10050
      DO 400 J=1,NVEC                                                   LIT10060
      ANORM=0.0D0                                                       LIT10070
      NL=1+(J-1)*NM                                                     LIT10080
      NH=NL+NM-1                                                        LIT10090
      DO 200 I=NL,NH                                                    LIT10100
  200 ANORM=ANORM+V(I)*V(I)                                             LIT10110
      ANORM=DSQRT(ANORM)                                                LIT10120
      DO 300 I=NL,NH                                                    LIT10130
  300 V(I)=V(I)/ANORM                                                   LIT10140
  400 CONTINUE                                                          LIT10150
C                                                                       LIT10160
C     MODIFY VECTORS                                                    LIT10170
C                                                                       LIT10180
```

```
      DO 500 I=1,LP                                                     LIT10190
      DO 500 J=1,NVEC                                                   LIT10200
      JJ=I+(J-1)*NM                                                     LIT10210
      IF(N2.EQ.1) GO TO 450                                             LIT10220
      V(JJ)=V(JJ)*XM(I)                                                 LIT10230
      GO TO 500                                                         LIT10240
  450 V(JJ)=V(JJ)/XM(I)                                                 LIT10250
  500 CONTINUE                                                          LIT10260
      IF(M.GT.0) RETURN                                                 LIT10270
      NLIM=NEV/2                                                        LIT10280
      DO 600 I=1,NLIM                                                   LIT10290
      ATEMP=E(I)                                                        LIT10300
      II=NEV-I+1                                                        LIT10310
      E(I)=E(II)                                                        LIT10320
  600 E(II)=ATEMP                                                       LIT10330
      NLIM=NVEC/2                                                       LIT10340
      DO 700 I=1,NLIM                                                   LIT10350
      DO 700 J=1,NM                                                     LIT10360
      JJ=J+(I-1)*NM                                                     LIT10370
      JJJ=NEL-NM*I+J                                                    LIT10380
      ATEMP=V(JJ)                                                       LIT10390
      V(JJ)=V(JJJ)                                                      LIT10400
  700 V(JJJ)=ATEMP                                                      LIT10410
      RETURN                                                            LIT10420
      END                                                               LIT10430


      SUBROUTINE JACVAT(A,N,NOYES,EIVU,EIVR,NDIM)                       LIT10440
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT10450
      DIMENSION A(NDIM,NDIM),EIVU(NDIM),EIVR(NDIM,NDIM)                 LIT10460
      IF(N-1)20,23,21                                                   LIT10470
   20 PRINT 22,N                                                        LIT10480
   22 FORMAT(4H N= ,I3,68H IS TOO SMALL.  LIMIT IS 1.  RETURN TO CALLINGLIT10490
     1 ROUTINE FROM JACVAT. )                                           LIT10500
      RETURN                                                            LIT10510
   23 PRINT 24, A(1,1)                                                  LIT10520
   24 FORMAT (24H IN JACVAT , MATRIX A = ,E14.6)                        LIT10530
      RETURN                                                            LIT10540
   21 IF(N-160)1,1,3                                                    LIT10550
    3 PRINT 2,N                                                         LIT10560
    2 FORMAT(3H N=,I5,70H IS TOO LARGE.  LIMIT IS 160.  RETURN TO CALLI-LIT10570
     1NG ROUTINE FROM JACVAT. )                                         LIT10580
      RETURN                                                            LIT10590
    1 IF(NOYES)99,102,99                                                LIT10600
   99 CONTINUE                                                          LIT10610
      DO 101 J=1,N                                                      LIT10620
      DO 100 I=1,N                                                      LIT10630
  100 EIVR(I,J)=0.0                                                     LIT10640
```

```
101 EIVR(J,J)=1.0                                                          LIT10650
102 ATOP=0.                                                                LIT10660
    DO 112 J=1,N                                                           LIT10670
    DO 111 I=1,J                                                           LIT10680
    IF(A(I,J)-A(J,I))90,103,90                                             LIT10690
 90 PRINT 106,N,N                                                          LIT10700
106 FORMAT(14H IN JACVAT (A(,I3,1H,,I3,3H)),)                              LIT10710
    PRINT 108,I,J,J,I                                                      LIT10720
108 FORMAT(3H A(,I3,1H,,I3,10H)  AND  A(,I3,1H,,I3,54H) WERE UNEQUAL,     LIT10730
   1SO THEY WERE REPLACED WITH THEIR MEAN )                                LIT10740
    A(I,J)=.5*(A(I,J)+A(J,I))                                              LIT10750
    A(J,I)=A(I,J)                                                          LIT10760
103 CONTINUE                                                               LIT10770
    IF(ATOP-DABS(A(I,J)))104,111,111                                       LIT10780
104 ATOP=DABS(A(I,J))                                                      LIT10790
111 CONTINUE                                                               LIT10800
112 EIVU(J)=A(J,J)                                                         LIT10810
    IF(ATOP)109,109,113                                                    LIT10820
109 PRINT 110                                                              LIT10830
110 FORMAT(26H IN JACVAT, MATRIX A  = 0 )                                  LIT10840
    RETURN                                                                 LIT10850
113 AVGF=DFLOAT(N*(N-1))*.55                                               LIT10860
    D=0.0                                                                  LIT10870
    DO 114 JJ=2,N                                                          LIT10880
    DO 114 II=2,JJ                                                         LIT10890
    S=A(II-1,JJ)/ATOP                                                      LIT10900
114 D=S*S+D                                                                LIT10910
    DSTOP=(1.D-08)*D                                                       LIT10920
    THRSH =DSQRT (D/AVGF)*ATOP                                             LIT10930
115 IFLAG=0                                                                LIT10940
    DO 130 JCOL=2,N                                                        LIT10950
    JCOL1=JCOL-1                                                           LIT10960
    DO 130 IROW=1,JCOL1                                                    LIT10970
    AIJ=A(IROW,JCOL)                                                       LIT10980
    IF(DABS(AIJ)-THRSH)130,130,117                                         LIT10990
117 AII=A(IROW,IROW)                                                       LIT11000
    AJJ=A(JCOL,JCOL)                                                       LIT11010
    S=AJJ-AII                                                              LIT11020
    IF(DABS(AIJ)-1.D-09*DABS(S))130,130,118                                LIT11030
118 IFLAG=1                                                                LIT11040
    IF(1.D-10*DABS(AIJ)-DABS(S))116,119,119                                LIT11050
119 S=.707106781                                                           LIT11060
    C=S                                                                    LIT11070
    GO TO 120                                                              LIT11080
116 T=AIJ/S                                                                LIT11090
    S=0.25/DSQRT(0.25+T*T)                                                 LIT11100
    C=DSQRT(0.5+S)                                                         LIT11110
    S=2.*T*S/C                                                             LIT11120
```

```
  120 DO 121 I=1,IROW
      T=A(I,IROW)
      U=A(I,JCOL)
      A(I,IROW)=C*T-S*U
  121 A(I,JCOL)=S*T+C*U
      I2=IROW+2
      IF(I2-JCOL)127,127,123
  127 CONTINUE
      DO 122 I=I2,JCOL
      T=A(I-1,JCOL)
      U=A(IROW,I-1)
      A(I-1,JCOL)=S*U+C*T
  122 A(IROW,I-1)=C*U-S*T
  123 A(JCOL,JCOL)=S*AIJ+C*AJJ
      A(IROW,IROW)=C*A(IROW,IROW)-S*(C*AIJ-S*AJJ)
      DO 124 J=JCOL,N
      T=A(IROW,J)
      U=A(JCOL,J)
      A(IROW,J)=C*T-S*U
  124 A(JCOL,J)=S*T+C*U
      IF(NOYES)131,126,131
  131 CONTINUE
      DO 125 I=1,N
      T=EIVR(I,IROW)
      EIVR(I,IROW)=C*T-EIVR(I,JCOL)*S
  125 EIVR(I,JCOL)=S*T+EIVR(I,JCOL)*C
  126 CONTINUE
      S=AIJ/ATOP
      D=D-S*S
      IF(D-DSTOP)1260,129,129
 1260 D=0.
      DO 128 JJ=2,N
      DO 128 II=2,JJ
      S=A(II-1,JJ)/ATOP
  128 D=S*S+D
      DSTOP=(1.D-08)*D
  129 THRSH=DSQRT(D/AVGF)*ATOP
  130 CONTINUE
      IF(IFLAG)115,134,115
  134 T=A(1,1)
      A(1,1)=EIVU(1)
      EIVU(1)=T
      DO 132 J=2,N
      T=A(J,J)
      A(J,J)=EIVU(J)
      EIVU(J)=T
      DO 132 I=2,J
  132 A(I-1,J)=A(J,I-1)
```

```
C   CRDER VECTORS AND VALUES
      DO 200 I=1,N
       DO 200 J=I,N
      IF(EIVU(I).GE.EIVU(J)) GO TO 200
      TEMP=EIVU(I)
      EIVU(I)=EIVU(J)
      EIVU(J)=TEMP
      DO 195 K=1,N
      TEMP=EIVR(K,I)
      EIVR(K,I)=EIVR(K,J)
  195 EIVR(K,J)=TEMP
  200 CONTINUE
  133 RETURN
      END


      SUBROUTINE PLOT(NA,NB,NAA,NAB,NAC,NBA,NBB,NBC,INR)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON       NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)
     1          ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)
     2,NN(100),NW1(80)
      REAL*8 NAME
      INTEGER*2 IGRID(101)
      INTEGER*4 ICHAR(11)/'  + ',' ',' - ',' | ',' Y ',' X ',
     *' A ',' B ',' * ',' O ',' . '/
      NNN=6
      KKK=65
      IF(INR.EQ.1) NNN=8
      IF(INR.EQ.1) KKK=81
      KKJ=KKK-1
      PNN=NNN
      XMAX=A(NA)
      XMIN=XMAX
      YMAX=A(NA+1)
      YMIN=YMAX
      IF(INR) 48,48,49
   49 WRITE(8,99)
   48 DO 10 K=NA,NB,2
      IF(A(K).GT.XMAX) XMAX=A(K)
      IF(A(K).LT.XMIN) XMIN=A(K)
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)
   10 IF(A(K+1).LT.YMIN) YMIN=A(K+1)
      IF(NAA.EQ.0) GO TO 60
      DO 50 K=NAA,NBA,2
      IF(A(K).GT.XMAX) XMAX=A(K)
      IF(A(K).LT.XMIN) XMIN=A(K)
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)
   50 IF(A(K+1).LT.YMIN) YMIN=A(K+1)
```

```
      IF(NAB.EQ.0) GO TO 60                                          LIT12070
      DO 51 K=NAB,NBB,2                                              LIT12080
      IF(A(K).GT.XMAX) XMAX=A(K)                                     LIT12090
      IF(A(K).LT.XMIN) XMIN=A(K)                                     LIT12100
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)                                 LIT12110
   51 IF(A(K+1).LT.YMIN) YMIN=A(K+1)                                 LIT12120
      IF(NAC.EQ.0) GO TO 60                                          LIT12130
      DO 52 K=NAC,NBC,2                                              LIT12140
      IF(A(K).GT.XMAX) XMAX=A(K)                                     LIT12150
      IF(A(K).LT.XMIN) XMIN=A(K)                                     LIT12160
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)                                 LIT12170
   52 IF(A(K+1).LT.YMIN) YMIN=A(K+1)                                 LIT12180
   60 XRANGE=XMAX-XMIN                                               LIT12190
      IF(XRANGE.EQ.0.0) XRANGE=1.0                                   LIT12200
      YRANGE=YMAX-YMIN                                               LIT12210
      IF(YRANGE.EQ.0.0) YRANGE=1.0                                   LIT12220
      XT=XMAX*XMIN                                                   LIT12230
      YT=YMAX*YMIN                                                   LIT12240
      IF(YT.LT.0.0) IXAX=100.0*(-YMIN)/YRANGE+1.5                    LIT12250
      IF(XT.LT.0.0) IYAX=KKJ- KKJ*XMAX/XRANGE+1.5                    LIT12260
      IF(XMIN.GE.0.0) IYAX=1                                         LIT12270
      IF(XMAX.LE.0.0) IYAX=KKK                                       LIT12280
      IF(YMIN.GE.0.0) IXAX=1                                         LIT12290
      IF(YMAX.LE.0.0) IXAX=101                                       LIT12300
      YINCR=YRANGE/10.0                                              LIT12310
      XINCR=PNN*(XRANGE/KKJ)                                         LIT12320
      DO  11 LINE=1,KKK                                              LIT12330
      DO 12 J=1,101                                                  LIT12340
   12 IGRID(J)=ICHAR(2)                                              LIT12350
      IF(LINE-IYAX) 13,14,13                                         LIT12360
   14 DO 15 K=1,101                                                  LIT12370
   15 IGRID(K)=ICHAR(3)                                              LIT12380
      DO 25 LL=1,10                                                  LIT12390
      LY=IXAX-10*LL                                                  LIT12400
      IF(LY.LT.0.0) GO TO 26                                         LIT12410
      IGRID(LY)=ICHAR(5)                                             LIT12420
      IF(XT.GT.0.0) IGRID(LY)=ICHAR(8)                               LIT12430
   26 LY=IXAX+10*LL                                                  LIT12440
      IF(LY.GT.100) GO TO 25                                         LIT12450
      IGRID(LY)=ICHAR(5)                                             LIT12460
      IF(XT.GT.0.0) IGRID(LY)=ICHAR(8)                               LIT12470
   25 CONTINUE                                                       LIT12480
   13 IGRID(IXAX)=ICHAR(4)                                           LIT12490
      DO 27 JK=1,10                                                  LIT12500
      JX=IYAX-PNN*JK                                                 LIT12510
      IF(JX.LT.0.0) GO TO 28                                         LIT12520
      IF(JX-LINE) 28,29,28                                           LIT12530
   29 IGRID(IXAX)=ICHAR(6)                                           LIT12540
```

```
      IF(YT.GT.0.0) IGRID(IXAX)=ICHAR(7)                              LIT12550
   28 JX=IYAX+PNN*JK                                                  LIT12560
      IF(JX.GT.KKJ) GO TO 27                                          LIT12570
      IF(JX-LINE) 27,30,27                                            LIT12580
   30 IGRID(IXAX)=ICHAR(6)                                            LIT12590
      IF(YT.GT.0.0) IGRID(IXAX)=ICHAR(7)                              LIT12600
   27 CONTINUE                                                        LIT12610
      DO 16 I=NA,NB,2                                                 LIT12620
      IPTX=KKJ-KKJ*(XMAX-A(I))/XRANGE+1.5                             LIT12630
      IF(IPTX.LT.1) IPTX=1                                            LIT12640
      IF(IPTX.GT.KKJ) IPTX=KKK                                        LIT12650
      IF(IPTX-LINE) 16,17,16                                          LIT12660
   17 IPTY=100.0*(A(I+1)-YMIN)/YRANGE+1.5                             LIT12670
      IGRID(IPTY)=ICHAR(1)                                            LIT12680
   16 CONTINUE                                                        LIT12690
      IF(NAA.EQ.0) GO TO 97                                           LIT12700
      DO 53 IA=NAA,NBA,2                                              LIT12710
      IPTX=KKJ-KKJ*(XMAX-A(IA))/XRANGE+1.5                            LIT12720
      IF(IPTX.LT.1) IPTX=1                                            LIT12730
      IF(IPTX.GT.KKJ) IPTX=KKK                                        LIT12740
      IF(IPTX-LINE) 53,67,53                                          LIT12750
   67 IPTY=100.0*(A(IA+1)-YMIN)/YRANGE+1.5                            LIT12760
      IGRID(IPTY)=ICHAR(9)                                            LIT12770
   53 CONTINUE                                                        LIT12780
      IF(NAB.EQ.0) GO TO 97                                           LIT12790
      DO 54 IB=NAB,NBB,2                                              LIT12800
      IPTX=KKJ-KKJ*(XMAX-A(IB))/XRANGE+1.5                            LIT12810
      IF(IPTX.LT.1) IPTX=1                                            LIT12820
      IF(IPTX.GT.KKJ) IPTX=KKK                                        LIT12830
      IF(IPTX-LINE) 54,66,54                                          LIT12840
   66 IPTY=100.0*(A(IB+1)-YMIN)/YRANGE+1.5                            LIT12850
      IGRID(IPTY)=ICHAR(10)                                           LIT12860
   54 CONTINUE                                                        LIT12870
      IF(NAC.EQ.0) GO TO 97                                           LIT12880
      DO 55 IC=NAC,NBC,2                                              LIT12890
      IPTX=KKJ-KKJ*(XMAX-A(IC))/XRANGE+1.5                            LIT12900
      IF(IPTX.LT.1) IPTX=1                                            LIT12910
      IF(IPTX.GT.KKJ) IPTX=KKK                                        LIT12920
      IF(IPTX-LINE) 55,68,55                                          LIT12930
   68 IPTY=100.0*(A(IC+1)-YMIN)/YRANGE+1.5                            LIT12940
      IGRID(IPTY)=ICHAR(11)                                           LIT12950
   55 CONTINUE                                                        LIT12960
   97 IF(INR) 42,42,41                                                LIT12970
   42 WRITE(6,20) (IGRID(I),I=1,101)                                  LIT12980
      GO TO 11                                                        LIT12990
   41 WRITE(8,20) (IGRID(I),I=1,101)                                  LIT13000
   11 CONTINUE                                                        LIT13010
      IF(XT.LE.0.0) YYY=0.0                                           LIT13020
```

```
      IF(YT.LE.0.0) XXX=0.0                                             LIT13030
      IF(XMIN.GE.0.0) XXX=XMIN                                          LIT13040
      IF(YMAX.LE.0.0) YYY=YMAX                                          LIT13050
      IF(YMIN.GE.0.0) YYY=YMIN                                          LIT13060
      IF(XMAX.LE.0.0) XXX=XMIN+XRANGE+XINCR/PNN                         LIT13070
      IF(INR) 43,43,44                                                  LIT13080
   43 WRITE(6,22) XINCR,YINCR                                           LIT13090
      WRITE(6,23) XXX,YYY                                               LIT13100
      GO TO 45                                                          LIT13110
   44 WRITE(8,22) XINCR,YINCR                                           LIT13120
      WRITE(8,23) XXX,YYY                                               LIT13130
   45 RETURN                                                            LIT13140
   20 FORMAT(15X,101A1)                                                 LIT13150
   99 FORMAT(1H1)                                                       LIT13160
   22 FORMAT(12H  X-----X = ,F6.2,10X,15H  Y---------Y = ,F6.2)         LIT13170
   23 FORMAT(11H ORGIN: X= ,F6.2,3H Y=,F6.2)                            LIT13180
      END                                                               LIT13190


      SUBROUTINE ITGRAL(NA,INR)                                         LIT13200
      IMPLICIT REAL*8 (A-H,O-Z)                                         LIT13210
      COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)      LIT13220
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)  LIT13230
     2,NN(100),NW1(80)                                                  LIT13240
      DIMENSION C(16),X(6),W(6)                                         LIT13250
      SUM=0.0D0                                                         LIT13260
      SUM2=0.0D0                                                        LIT13270
      SUM4=0.0D0                                                        LIT13280
      SUM8=0.0D0                                                        LIT13290
      SUM16=0.0D0                                                       LIT13300
      DO 9 I=1,16                                                       LIT13310
    9 C(I)=0.0D0                                                        LIT13320
      X(1)=-.932469514203152D0                                          LIT13330
      X(2)=-.661209386466264 5D0                                        LIT13340
      X(3)=-.238619186083196 9D0                                        LIT13350
      X(4)=-X(3)                                                        LIT13360
      X(5)=-X(2)                                                        LIT13370
      X(6)=-X(1)                                                        LIT13380
      W(1)=.171324492379170 3D0                                         LIT13390
      W(2)=.360761573048138 6D0                                         LIT13400
      W(3)=.467913934572691 0D0                                         LIT13410
      W(4)=W(3)                                                         LIT13420
      W(5)=W(2)                                                         LIT13430
      W(6)=W(1)                                                         LIT13440
      GO TO (1,2,3,4),INR                                               LIT13450
    1 H=A(NA)                                                           LIT13460
      XF=A(NA+1)                                                        LIT13470
      XL=A(NA+NR-1)                                                     LIT13480
```

```
      NV=NR-1                                                           LIT13490
      NNV=NR-2                                                          LIT13500
      IF(NV.LT.3) GO TO 23                                              LIT13510
      DO 20 I=3,NV,2                                                    LIT13520
   20 SUM4=SUM4+A(NA+I-1)                                               LIT13530
      IF(NNV.LT.4) GO TO 23                                             LIT13540
      DO 21 I=4,NNV,2                                                   LIT13550
   21 SUM2=SUM2+A(NA+I-1)                                               LIT13560
   23 SUM=(H/3.0)*(XF+XL+4.0*SUM4+2.0*SUM2)                             LIT13570
      WRITE(6,61) SUM                                                   LIT13580
      GO TO 99                                                          LIT13590
    2 H=A(NA)                                                           LIT13600
      HH=A(NA+1)                                                        LIT13610
      IJ=NR-2                                                           LIT13620
      ZZ=IJ                                                             LIT13630
      IK=DSQRT(ZZ)                                                      LIT13640
      NB=(IK-1)/2                                                       LIT13650
      NC=NB-1                                                           LIT13660
      ND=IK-2                                                           LIT13670
      NE=ND-1                                                           LIT13680
      NF=IK-3                                                           LIT13690
      SUM=A(NA+2)+A(NA+IK+1)+A(NA+NR-IK)+A(NA+NR-1)                     LIT13700
      DO 31 I=1,ND,2                                                    LIT13710
   31 SUM4=SUM4+A(NA+I+2)+A(NA+NR-IK+1)                                 LIT13720
      IF(NF.LT.1) GO TO 30                                              LIT13730
      DO 38 I=1,NF,2                                                    LIT13740
   38 SUM2=SUM2+A(NA+I+3)+A(NA+NR-IK+2)                                 LIT13750
   30 DO 32 J=1,ND,2                                                    LIT13760
      DO 32 JJ=1,ND,2                                                   LIT13770
   32 SUM16=SUM16+A(NA+J*IK+JJ+2)                                       LIT13780
      DO 33 K=1,ND,2                                                    LIT13790
      DO 33 KK=1,NE,2                                                   LIT13800
   33 SUM8=SUM8+A(NA+K*IK+KK+3)                                         LIT13810
      DO 34 L=2,NF,2                                                    LIT13820
      DO 34 LL=1,ND,2                                                   LIT13830
   34 SUM8=SUM8+A(NA+L*IK+LL+2)                                         LIT13840
      DO 35 M=2,NF,2                                                    LIT13850
      DO 35 MM=1,NE,2                                                   LIT13860
   35 SUM4=SUM4+A(NA+M*IK+MM+3)                                         LIT13870
      DO 36 MN=1,ND,2                                                   LIT13880
   36 SUM4=SUM4+A(NA+MN*IK+2)+A(NA+MN*IK+IK+1)                          LIT13890
      IF(NF.LT.2) GO TO 39                                              LIT13900
      DO 37 MNN=2,NF,2                                                  LIT13910
   37 SUM2=SUM2+A(NA+MNN*IK+2)+A(NA+MNN*IK+IK+1)                        LIT13920
   39 SUM=(SUM+2*SUM2+4*SUM4+8*SUM8+16*SUM16)*(H*HH)/9.0D0              LIT13930
      WRITE(6,62) SUM                                                   LIT13940
      GO TO 99                                                          LIT13950
    3 NB=NR-2                                                           LIT13960
```

```
      XL=A(NA)
      XU=A(NA+1)
      DO 41 I=1,NB
   41 C(I)=A(NA+I+1)
      RANGE=XU-XL
      XM=(XU+XL)/2.0DO
      DO 42 I=1,6
      PT=X(I)*(XU-XM)+XM
      FX=C(1)*PT**11+C(2)*PT**10+C(3)*PT**9+C(4)*PT**8+C(5)*PT**7+
     1C(6)*PT**6+C(7)*PT**5+C(8)*PT**4+C(9)*PT**3+C(10)*PT**2+C(11)*PT
     2+C(12)
   42 SUM=FX*W(I)+SUM
      SUM=SUM*RANGE/2.0DO
      WRITE(6,61) SUM
      GO TO 99
    4 NB=NR-4
      XL=A(NA)
      XU=A(NA+1)
      YL=A(NA+2)
      YU=A(NA+3)
      XRANGE=XU-XL
      YRANGE=YU-YL
      XM=(XU+XL)/2.0DO
      YM=(YU+YL)/2.0DO
      DO 51 I=1,NB
   51 C(I)=A(NA+I+3)
      DO 53 I=1,6
      DO 53 J=1,6
      PTX=X(I)*(XU-XM)+XM
      PTY=X(J)*(YU-YM)+YM
      FX=C(1)*PTX**3*PTY**3+C(2)*PTX**3*PTY**2+C(3)*PTX**3*PTY+
     1C(4)*PTX**3+C(5)*PTX**2*PTY**3+C(6)*PTX**2*PTY**2+C(7)*PTX**2*PTY
     2+C(8)*PTX**2+C(9)*PTX*PTY**3+C(10)*PTX*PTY**2+C(11)*PTX*PTY+
     3C(12)*PTX+C(13)*PTY**3+C(14)*PTY**2+C(15)*PTY+C(16)
   53 SUM=FX*W(I)*W(J)+SUM
      SUM=SUM*XRANGE*YRANGE/4.0DO
      WRITE(6,62) SUM
   99 RETURN
   61 FORMAT(6H AREA=,1D25.16)
   62 FORMAT(8H VOLUME=,1D25.16)
   25 FORMAT(12F6.4)
      END
```

```
      SUBROUTINE POLFIT(XA,XB,*)
      IMPLICIT REAL *8 (A-H,O-Z)
      COMMON        XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)
     1              ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)
     2,NN(100),NW1(80)
      DIMENSION CM(256),COEF(16),CM1(16),PV(16),CV(15),GSP(16)
      NC=1
      NR=16
      CALL MFIND(XA,&5)
      NA=NX
      HX=A(NA)
      HY=A(NA+1)
      DO 10 I=1,16
   10 PV(I)=A(NA+1+I)
      L=0
      DO 100 I=1,4
      Y=I-1
      DO 100 J=1,4
      X=J-1
      DO 50 II=1,16
   50 COEF(II)=0.0D0
      CALL P(X,Y,COEF)
      DO 70 K=1,16
   70 CM(L*16+K)=COEF(K)
      L=L+1
  100 CONTINUE
      CALL INVERT(CM,CM1,GSP,16)
      CALL MULT(16,CM,16,PV,1,CV)
      CV(1)=CV(1)/(HX**3*HY**3)
      CV(2)=CV(2)/(HX**3*HY**2)
      CV(3)=CV(3)/(HX**3*HY)
      CV(4)=CV(4)/(HX**3)
      CV(5)=CV(5)/(HX**2*HY**3)
      CV(6)=CV(6)/(HX**2*HY**2)
      CV(7)=CV(7)/(HX**2*HY)
      CV(8)=CV(8)/(HX**2)
      CV(9)=CV(9)/(HX*HY**3)
      CV(10)=CV(10)/(HX*HY**2)
      CV(11)=CV(11)/(HX*HY)
      CV(12)=CV(12)/(HX)
      CV(13)=CV(13)/(HY**3)
      CV(14)=CV(14)/HY**2
      CV(15)=CV(15)/HY
      NR=16
      NC=1
      CALL MLIST(XB,&5)
      CALL MFIND(XB,&5)
      NA=NX
```

```
      DO 200 I=1,16
  200 A(NA-1+I)=CV(I)
      RETURN
    5 RETURN 1
      END

      SUBROUTINE P(X,Y,COEF)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION COEF(16)
      IF(X.EQ.0.0D0.AND.Y.EQ.0.0D0) GO TO 10
      GO TO 15
   10 COEF(16)=1.0D0
      RETURN
   15 CONTINUE
      IF(X.EQ.0.0D0) GO TO 20
      GO TO 25
   20 COEF(13)=Y**3
      COEF(14)=Y**2
      COEF(15)=Y
      COEF(16)=1.0D0
      RETURN
   25 CONTINUE
      IF(Y.EQ.0.0D0) GO TO 30
      GO TO 35
   30 COEF(4)=X**3
      COEF(8)=X**2
      COEF(12)=X
      COEF(16)=1.0D0
      RETURN
   35 CONTINUE
      COEF(1)=(X**3)*(Y**3)
      DO 100 I=2,5
      IM=I-1
      IF(I.GT.4) GO TO 50
      COEF(I)=COEF(IM)/Y
   50 CONTINUE
      DO 100 J=2,4
      JJ=(J-1)*4+IM
      JM=JJ-4
      COEF(JJ)=COEF(JM)/X
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CONTUR(XA,XB,NAR,NAC,NOC,*)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON        XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)
     1             ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)
     2,NN(100),NW1(80)
      DIMENSION  ISYMB(42),BV(21),C(16),IGRID(101),U(16)
      INTEGER*2 GRAPH(16),GRAPH1(16),GRAPH2(16),GRAPH3(16),GRAPH4(16)
      DATA ISYMB/1H ,1HO,1H ,1HA,1H ,1HB,1H ,1HC,1H ,1HD,1H ,1HE
     1,1H ,1HF,1H ,1HG,1H ,1HH,1H ,1HI,1H ,1HJ,1H ,1HQ,1H ,1HR,1H ,1HS,
     21H ,1HT,1H ,1HU,1H ,1HV,1H ,1HW,1H ,1HX,1H ,1HY,1H ,1HZ/
      DATA IBLK/1H /
      DATA GRAPH /'U1-------U2--------U3--------U4 '/
      DATA GRAPH1/'U5-------U6--------U7--------U8 '/
      DATA GRAPH2/'U9-------U10-------U11-------U12'/
      DATA GRAPH3/'U13------U14-------U15-------U16'/
      DATA GRAPH4/'|        |         |         |  '/
      GO TO (474,475),NAR
  474 CALL POLFIT(XA,XB,P5)
      CALL MFIND(XA,&5)
      NA=NX
      HX=A(NA)
      HY=A(NA+1)
      XL=0.0D0
      YL=0.0D0
      XRANGE=3.0D0*HX
      YRANGE=3.0D0*HY
      CALL MFIND(XB,&5)
      NB=NX
      DO 476 I=1,16
      U(I) =A(NA+1+I)
  476 C(I)=A(NB+I-1)
      GO TO 480
  475 CALL MFIND(XA,&5)
      NA=NX
      XL=A(NA)
      XU=A(NA+1)
      YL=A(NA+2)
      YU=A(NA+3)
      XRANGE=XU-XL
      YRANGE=YU-YL
      DO 477 I=1,16
  477 C(I)=A(NA+I+3)
  480 IJK=65
      IF(NAC.GT.1) IJK=80
      PJK=IJK-1.0
      GO TO (20,21),NAC
   20 GO TO (1,2),NAR
    1 WRITE(6,101)
```

```
      WRITE(6,300)  GRAPH
      DO 6 I=1,6
    6 WRITE(6,300)  GRAPH4
      WRITE(6,300)  GRAPH1
      DO 7 I=1,6
    7 WRITE(6,300)  GRAPH4
      WRITE(6,300)  GRAPH2
      DO 8 I=1,6
    8 WRITE(6,300)  GRAPH4
      WRITE(6,300)  GRAPH3
      WRITE(6,101)
      WRITE(6,301)  U(1),U(2),U(3),U(4),U(5),U(6),U(7),U(8)
      WRITE(6,302)  U(9),U(10),U(11),U(12),U(13),U(14),U(15),U(16)
      JMB=4-NOC
      DO 60 L=1,JMB
   60 WRITE(6,100)
      GO TO 4
    2 WRITE(6,103)
      WRITE(6,303)  C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8)
      WRITE(6,304)  C(9),C(10),C(11),C(12),C(13),C(14),C(15),C(16)
      JMB=20-NOC
      DO 61 L=1,JMB
   61 WRITE(6,100)
      GO TO 4
   21 GO TO (22,23),NAR
   22 WRITE(8,101)
      WRITE(8,300)  GRAPH
      DO 24 I=1,8
   24 WRITE(8,300)  GRAPH4
      WRITE(8,300)  GRAPH1
      DO 25 I=1,8
   25 WRITE(8,300)  GRAPH4
      WRITE(8,300)  GRAPH2
      DO 26 I=1,8
   26 WRITE(8,300)  GRAPH4
      WRITE(8,300)  GRAPH3
      WRITE(8,101)
      WRITE(8,301)  U(1),U(2),U(3),U(4),U(5),U(6),U(7),U(8)
      WRITE(8,302)  U(9),U(10),U(11),U(12),U(13),U(14),U(15),U(16)
      JMB=6-NOC
      DO 62 L=1,NCC
   62 WRITE(8,100)
      GO TO 4
   23 WRITE(8,105)
      WRITE(8,303)  C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8)
      WRITE(8,304)  C(9),C(10),C(11),C(12),C(13),C(14),C(15),C(16)
      JMB=9-NOC
      DO 63 L=1,JMB
```

```
63 WRITE(8,100)                                                              LIT16250
 4 PMAX=-1.0D70                                                              LIT16260
   PMIN= 1.0D70                                                              LIT16270
   DO 10 I=1,IJK                                                             LIT16280
   DO 10 J=1,101                                                             LIT16290
   X1=J-1                                                                    LIT16300
   Y1=I-1                                                                    LIT16310
   X=XL+(XRANGE*X1)/100.0D0                                                  LIT16320
   Y=YL+(YRANGE*Y1)/PJK                                                      LIT16330
   PP=C(1)*X**3*Y**3+C(2)*X**3*Y**2+C(3)*X**3*Y+C(4)*X**3 +                  LIT16340
  1C(5)*X**2*Y**3+C(6)*X**2*Y**2+C(7)*X**2*Y+C(8)*X**2+C(9)*X*Y**3+          LIT16350
  2C(10)*X*Y**2+C(11)*X*Y+C(12)*X+C(13)*Y**3+C(14)*Y**2+C(15)*Y+C(16)LIT16360
   IF(PP.GT.PMAX) PMAX=PP                                                    LIT16370
10 IF(PP.LT.PMIN) PMIN=PP                                                    LIT16380
   RANGE=PMAX-PMIN                                                           LIT16390
   IF(DABS(RANGE).GT.1.0D-10) GO TO 11                                       LIT16400
   WRITE(6,1000)                                                             LIT16410
   WRITE(6,1400) RANGE,PMAX,MIN                                              LIT16420
   GO TO 1500                                                                LIT16430
11 SCF=40./RANGE                                                             LIT16440
   DO 12 I=1,21                                                              LIT16450
   RR=I-1                                                                    LIT16460
12 BV(I)=2*RR/SCF+PMIN                                                       LIT16470
   GO TO (30,31),NAC                                                         LIT16480
30 WRITE(6,1300) BV(1),BV(1),BV(21)                                          LIT16490
   WRITE(6,1100) BV(2),BV(3),BV(4),BV(5),BV(6)                               LIT16500
   WRITE(6,1200) BV(7),BV(8),BV(9),BV(10),BV(11)                             LIT16510
   WRITE(6,1210) BV(12),BV(13),BV(14),BV(15),BV(16)                          LIT16520
   WRITE(6,1220) BV(17),BV(18),BV(19),BV(20),BV(21)                          LIT16530
   WRITE(6,102)                                                              LIT16540
   GO TO 40                                                                  LIT16550
31 WRITE(8,1300) BV(1),BV(1),BV(21)                                          LIT16560
   WRITE(8,1100) BV(2),BV(3),BV(4),BV(5),BV(6)                               LIT16570
   WRITE(8,1200) BV(7),BV(8),BV(9),BV(10),BV(11)                             LIT16580
   WRITE(8,1210) BV(12),BV(13),BV(14),BV(15),BV(16)                          LIT16590
   WRITE(8,1220) BV(17),BV(18),BV(19),BV(20),BV(21)                          LIT16600
   WRITE(8,104)                                                              LIT16610
40 CONTINUE                                                                  LIT16620
   DO 13 I=1,IJK                                                             LIT16630
   DO 14 K=1,101                                                             LIT16640
14 IGRID(K)=IBLK                                                             LIT16650
   DO 15 J=1,101                                                             LIT16660
   X1=J-1                                                                    LIT16670
   Y1=I-1                                                                    LIT16680
   X=XL+(XRANGE*X1)/100.0D0                                                  LIT16690
   Y=YL+(YRANGE*Y1)/PJK                                                      LIT16700
   PP=C(1)*X**3*Y**3+C(2)*X**3*Y**2+C(3)*X**3*Y+C(4)*X**3 +                  LIT16710
  1C(5)*X**2*Y**3+C(6)*X**2*Y**2+C(7)*X**2*Y+C(8)*X**2+C(9)*X*Y**3+          LIT16720
```

```
     2C(10)*X*Y**2+C(11)*X*Y+C(12)*X+C(13)*Y**3+C(14)*Y**2+C(15)*Y+C(16)
      KK=((PP-PMIN)*SCF+2.50001)
   15 IGRID(J)=ISYMB(KK)
      GO TO (50,51),NAC
   50 WRITE(6,99) (IGRID(II),II=1,101)
      GO TO 13
   51 WRITE(8,99) (IGRID(II),II=1,101)
   13 CONTINUE
      IF(NAC.EQ.1) WRITE(6,102)
      IF(NAC.EQ.2) WRITE(8,104)
   99 FORMAT(15X,101A1)
  100 FORMAT(/)
  101 FORMAT(////)
  102 FORMAT(//////)
  103 FORMAT(////)
  104 FORMAT(1H1)
  105 FORMAT(//////////////)
  300 FORMAT(25X,16A2)
  301 FORMAT(15X,5H U1 =,F12.6,5H U2 =,F12.6,5H U3 =,F12.6,5H U4 =,
     1F12.6,//,15X,5H U5 =,F12.6,5H U6 =,F12.6,5H U7 =,F12.6,5H U8 =,
     2F12.6,/)
  302 FORMAT(15X,5H U9 =,F12.6,5H U10=,F12.6,5H U11=,F12.6,5H U12=,
     1F12.6,//,15X,5H U13=,F12.6,5H U14=,F12.6,5H U15=,F12.6,5H U16=,
     2F12.6,////)
  303 FORMAT(15X,F12.6,5H X3Y3,F12.6,5H X3Y2,F12.6,5H X3Y ,F12.6,
     15H X3  ,//,15X,F12.6,5H X2Y3,F12.6,5H X2Y2,F12.6,5H X2Y ,F12.6,
     25H X2  ,/)
  304 FORMAT(15X,F12.6,5H XY3 ,F12.6,5H XY2 ,F12.6,5H XY  ,F12.6,
     15H X   ,//,15X,F12.6,5H Y3  ,F12.6,5H Y2  ,F12.6,5H Y   ,F12.6)
 1400 FORMAT(//,5X,13H THE RANGE IS,E15.6,/,5X,13H   MAXIMUM IS,E15.6,/,
     15X,13H   MINIMUM IS,E15.6)
 1000 FORMAT(1H1)
 1050 FORMAT(//)
 1100 FORMAT(5X,3H A=,F12.4,3X,3H B=,F12.4,3X,3H C=,F12.4,3X,3H D=,F12.4
     1,3X,3H E=,F12.4,/)
 1200 FORMAT(5X,3H F=,F12.4,3X,3H G=,F12.4,3X,3H H=,F12.4,3X,3H I=,F12.4
     1,3X,3H J=,F12.4,/)
 1210 FORMAT(5X,3H Q=,F12.4,3X,3H R=,F12.4,3X,3H S=,F12.4,3X,3H T=,F12.4
     1,3X,3H U=,F12.4,/)
 1220 FORMAT(5X,3H V=,F12.4,3X,3H W=,F12.4,3X,3H X=,F12.4,3X,3H Y=,F12.4
     1,3X,3H Z=,F12.4,/)
 1300 FORMAT(5X,3H O=,F15.10,5X,7H RANGE(,E15.6,5X,E15.6,2H ),/)
 1500 RETURN
    5 RETURN 1
      END
```

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13. ABSTRACT

The Matrix Interpretive System devised by Wilson and modified by Cantin has been transformed into an interactive program operable under a time sharing system. Several new commands have been added to extend the usefulness of the code and give it the capability to offline read, write and punch data, to plot graphs and contour maps and to integrate simple polynomial expressions.

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